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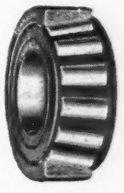

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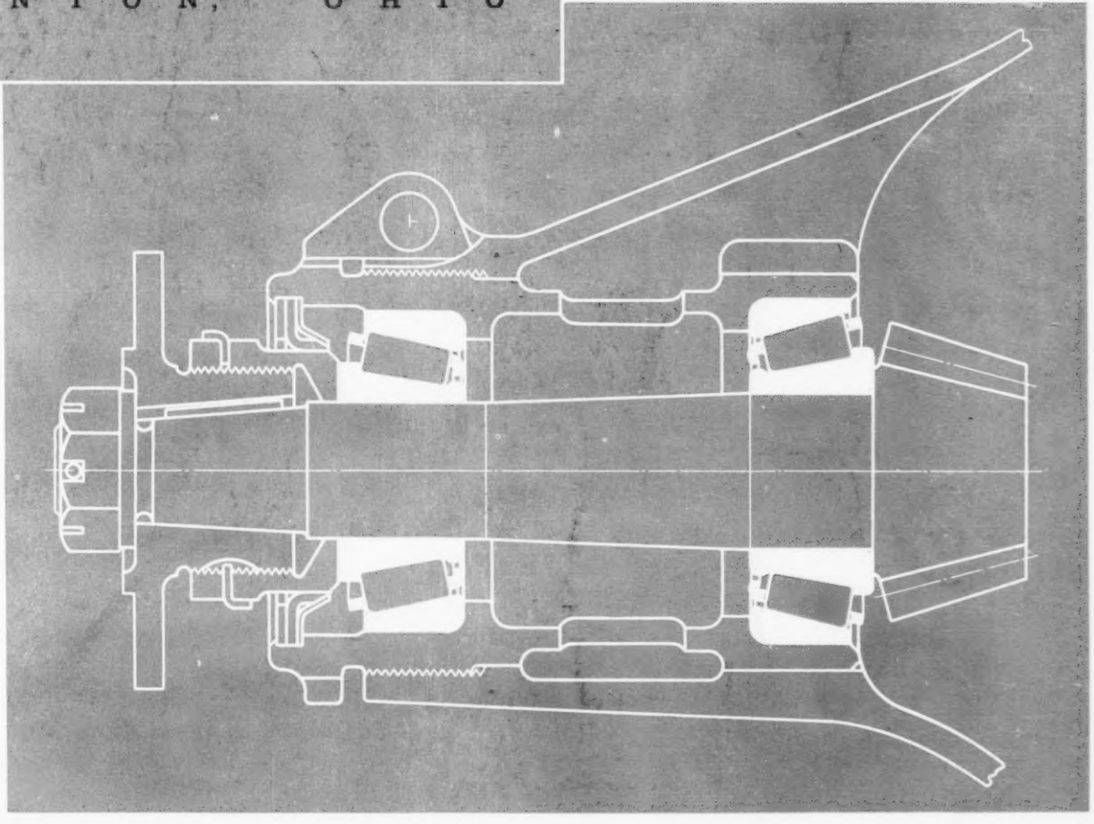

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AUTOMOTIVE INDUSTRIES
VOLUME 58 *Philadelphia, Saturday, June 23, 1928* NUMBER 25

Industry *in* Midst *of* Important *Engineering* Achievements

By
K. W. Stillman

SO much progress has been made in automotive design during the past decade that it sometimes has seemed as though there were few ways in which major improvements, at least, could be made on the existing product.

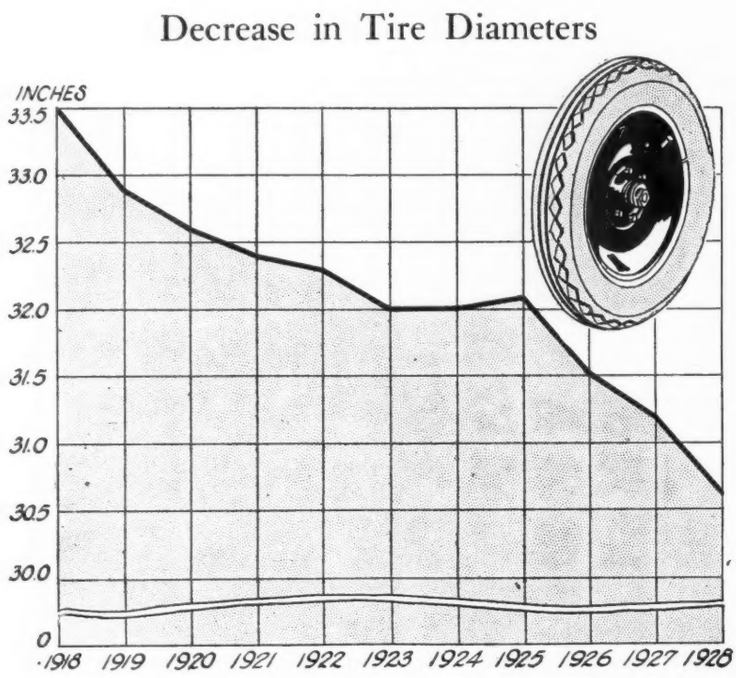
Despite this apparent inhibition to progress in design, engineers have been just as busy as ever. The work done during the past year, while not so spectacular, possibly, as when fundamental changes were being made, bids fair to result in the incorporation in 1929 models of more real engineering changes than for some years past, and very considerable contributions have been made toward increasing the value and service to be obtained from the automobiles offered for sale in 1928.

Engine power has been increased, new materials have been developed and adopted for specific automotive purposes, engine and chassis units have been changed in design to provide better performance and lower maintenance costs, and many other detailed refinements have been made, all of which tend to increase the value of automobiles as transportation units and greatly enhance their value in the minds of their owners.

In nearly all changes made in automotive design today, the desires of the car-owning and operating public have remarkable influence. The extent of car ownership in this country makes nearly every citizen a pseudo-expert on car performance and one who is not backward in expressing his opinions on all matters pertaining to his car.

Possibly nowhere has this element been so influential as in obtaining greater engine power. Congested traffic conditions have made quick acceleration and the power to get up ahead of traffic a very desirable consideration in any car. In addition to this, it is likely that the interest in racing has added somewhat to the public's enthusiasm for high power and speed.

In response to this desire engineers have increased the power of their engines generally so that today nearly 80 per cent of all models develop over 50 hp. as compared with conditions two years ago when there



were 10 per cent fewer models in this class. In 1926 some 8 per cent of all models were powered with engines developing less than 35 hp. but in 1928 this number has decreased to 3 per cent.

In obtaining increased power, the engineers had, in general, three methods open to them. The piston displacement might be increased, the engine speeds raised or the mean effective pressure increased by better "valving" or higher compression ratios.

All Methods Employed

All of these methods have been employed by various engineers, some preferring one and others another. In an accompanying chart are shown the trends during the past four years in the average piston displacement of passenger cars. This has been divided according to the number of cylinders in order to give a comparative picture and it is obvious that in each class the average displacement has increased.

For four-cylinder cars this trend has continued since 1925, the obvious indication being that their designers are trying to make their performance more nearly that of the six and eight-cylinder engines which have become so popular.

In the six-cylinder class, the trend of piston displacement was downward from 1925 to 1927 but it shot upward sharply in 1928. Very small changes have taken place in eight-cylinder engines, but whatever has occurred has been in the way of increasing the average displacement.

In increasing piston displacement, weight must, of course, be added to the engine and, logically, this should also call for increased weight in frames, axles, etc., so that real improvement in performance may not be as great as the increased output alone might indicate.

An apparently more attractive plan for increasing power has been to increase compression ratios. In 1926 but 3 per cent of all car models had compression ratios of 5 to 1 or over. Of the 1928 models 21 per cent are in this class, which illustrates clearly the eagerness with which engineers have grasped this means for obtaining more power.

Not only has the compression pressure of many engines been raised to rather high ratios, compared with former practice, but the general average of all cars has increased to almost an equal extent. This is shown by the fact that the number of models powered with engines of less than 4½ to 1 ratio has decreased over 21 per cent since 1926, a greater change than took place in the opposite direction in the highest ratio group.

Increased ratios are limited, of course, by trouble from detonation, but developments during recent years have made possible considerably higher compression ratios without trouble from this source than were feasible before. The increasingly wide distribution of anti-knock fuels has been an important factor, but of equal importance, at least from the long-time standpoint, has been better design of combustion chambers.

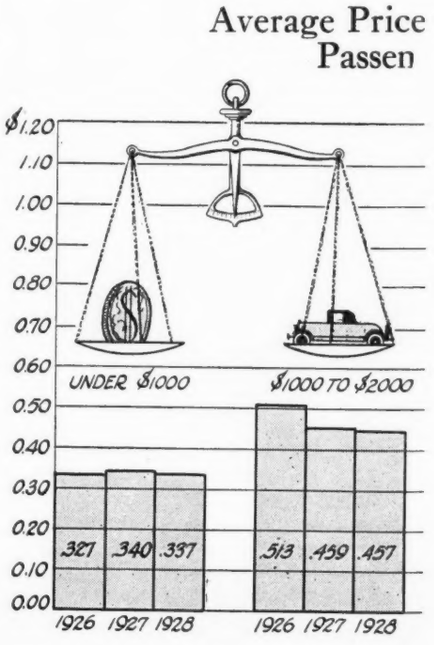
The latest development in this connection is aluminum cylinder heads, which have been adopted by one passenger car and one truck maker and are likely to be made use of by other makers in the near future.

When aluminum pistons were first employed it was found that the better heat distribution resulting permitted considerably higher compression ratios without trouble from detonation. Apparently this idea has simply been carried further in using aluminum cylinder heads so that still higher compression ratios can be used without developing hot spots.

The third method of increasing power, by speeding up the engine, has been adopted quite generally even by those engineers who have also employed the other methods. In six and eight-cylinder engines, speeds of over 3000 r.p.m. are becoming common, 20 models having this speed or better in 1928, an increase of seven models over 1927.

Four-cylinder engines have been influenced by this trend also, although not to the same extent as the sixes and eights. The most striking example is the new Ford engine which develops its maximum power at 2200 r.p.m., which is 600 r.p.m. greater than the speed of the Model T.

In the development of special materials for automotive use, possibly the most important item is the rapid adoption of aluminum alloys for pistons. Increasing engine speeds have made the question of reducing weights of rotating and reciprocating parts an important factor. One design is fitted with a strut of Invar—a nickel ferrous alloy—which has the property of not expanding when heated. This is used to counteract the influence of the difference in thermal expan-



sion between the alloy pistons and the cast iron cylinder block so that such pistons can be fitted with small clearances without danger of seizing.

Special metals have been developed for use in exhaust valves where the metal is exposed to the corroding influence of the exhaust gases. Since such characteristics are not required for intake valves, it has become common practice to make the two sets of valves of different material and even to make them of different size in order to avoid wrong assembly.

While vacuum fuel systems continue to be the most used, the development of very powerful cars which are run, at times, for considerable distances under full throttle, has led to the use of various types of pressure feed to offset the disadvantages of the low vacuum which prevails at the inlet manifold under these conditions.

Dual carburetors are being employed on eight-cylinder engines since it has been found that the flow conditions are so complicated with a single manifold that it is very difficult to secure uniform distribution to all cylinders.

Progress in improving the conditions under which an automotive engine operates has brought about developments in heat control, crankcase ventilation and purification of oil, fuel and air supplied to the engine.

Of this year's cars, over 80 per cent are equipped with oil cleaners of various types, which may be compared with conditions two years ago when only about 35 per cent were so equipped. Much the same progress has been made in air cleaners.

Among the types of oil cleaners included in the above figures is the crankcase ventilating type which, perhaps, should be considered separately from filters and other devices of this nature. The purpose of a crankcase ventilator, obviously, is not to clean dirt or other impurities from the oil but to eliminate the products of combustion which blow by the pistons into the crankcase and which, in sufficient quantities, cause dilution of the lubricant to a deleterious extent.

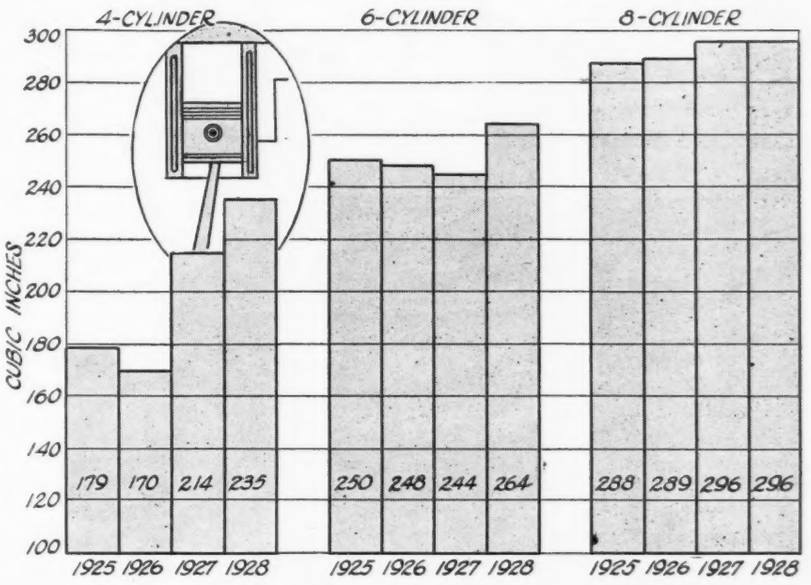
Engines should operate satisfactorily under extremes of temperature in the surrounding air and endeavors to accomplish this have been strenuous during recent years. Various methods of heat control have been developed which, while not unconditionally satisfactory, do provide better working conditions than heretofore.

An interesting change of recent years is in the return to four-point suspension for engines. Three-point suspension was adopted usually because it protected the engine against stresses resulting from frame distortion. With the growing popularity of closed bodies, which requires stiffer frames than were used formerly, four-point suspension is again being used not only because frame distortion is less than it once was, but also because this type of suspension adds to the stiffness of the frame.

Some degree of flexibility is being obtained, however, by the use of a rubber pad or block between the crankcase arm and the frame. This pad is designed so that there is no metal-to-metal contact between the engine and the frame and many high frequency vibrations originating in the former are absorbed.

Because of their simplicity, low cost of manufacture and ease of operation due to small spinning weight, single-plate clutches have become very popular. Some are provided with a vibration-damping device in their driven member designed to prevent any non-uniform motion of the crankshaft being transmitted to the gearset, thus causing gear chatter.

Piston Displacement—Passenger Cars



Per Pound
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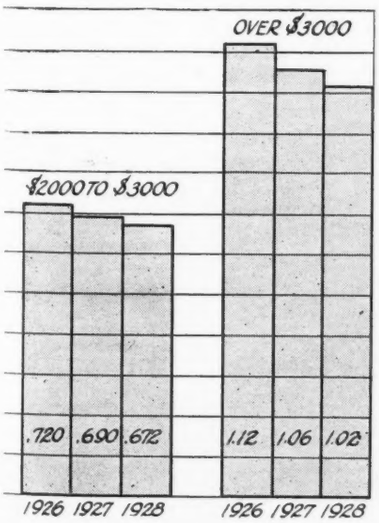


Tire Diameters Decrease

A rather remarkable change has taken place in wheel diameters during the past decade. As shown in an accompanying chart, the average outside diameter of tires used as standard equipment, has dropped from 33½ in. in 1918 to slightly over 30½ in. in 1928. This decrease has been quite steady with the exception of 1925 and 1926, which was the period of introduction of balloon tires when many engineers adopted the larger balloons but without decreasing their wheel diameters.

Increasing size of tire cross-sections has also brought about a tendency to increase the tread at the rear of the car by a few inches since the space available for comfortable rear seats, not any too large with high pressure tires, was reduced to an inadequate figure by the use of balloons.

With the exception of cars in the lowest price class, the price per pound of automobiles has been steadily decreasing, as is shown in another chart. The spread between the average prices per pound of cars in the various price classes expresses, to a large extent, the use of higher grade materials and more careful workmanship, as the price class increases.

Internal Gear Outstanding

Seems destined to displace con has not been neglected, how it more compact, stronger, quiet

By S. O.
Chief Engineer,

S. O. White

IT might seem to the lay observer, and perhaps even to many automotive engineers, that a gear is a gear. The rules governing its calculation and design have long been fixed and apparently not much is to be expected in the way of improvements, or of new ideas in design. It would seem that all automobile transmissions have the same general elements and differ chiefly in dimensions, materials and workmanship.

Perhaps this was more or less the situation at one time, but during the last few years transmissions and their gears have received intensive study and have been the subject of elaborate and extensive experimental research.

Referring first to general transmission design, the ever fertile brain of the non-technical inventor, whose name is legion, has forced us out of the rut. We were told that gears clashed and smashed and were hard to shift. There was consequently a wave of interest in the mechanical gear shift. The patent office is full of most ingenious devices for relieving the driver of the burden of shifting gears and supposedly doing it quietly and smoothly. Many of these worked very well, but they were complicated and expensive and the public very sensibly clung to the old "wobble stick." There is a sense of security and certainty about actually feeling the gears go into mesh and take hold.

About the same time, but approaching the gear-shift problem along another line, we had numerous constant mesh transmissions with various forms of engaging means. These mostly used the conventional shift lever, depending on some special engaging mechanism for a sure and silent shift, without clashing gears.

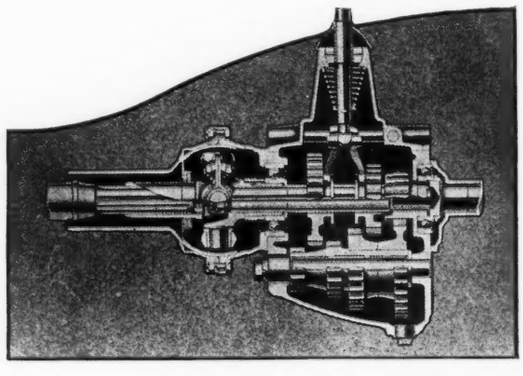
The goal of all transmission manufacturers is the silent transmission. The constant mesh gear idea was a move in that direction, employing in some cases helical or herringbone gears. It was also found that there were some mounting advantages, and in some designs a rigidity that contributed to the general quietness of the transmission. Some very satisfactory smooth running constant mesh transmissions have been made. Perhaps we are not through with this general type, but up to date, they have been found to have inherent weaknesses, manufacturing complications, or added costs and weight, out of proportion to the advantages gained. Most transmissions of this type carried as part of the scheme some more or less positive clutching device for picking up the various speeds easily and surely.

"Sure Shift" Not Always Safe

It proved to be dangerous to have a "sure shift" engaging arrangement for the lower speeds and reverse, for the reason that if it was not used intelligently, broken axle, universal, or transmission parts resulted from shifting into these lower ratios when traveling too fast. There is, however, a real advantage in such sure shifts for the two top speeds, where the ratios are such that they can be used at fast speeds without damage to the parts involved. Consequently, there may be a field for constant mesh gears for the next to top speed with the lower speeds arranged for more or less conventional sliding gears.

During this same period, and for some time previous, there have been many efforts to solve the hydraulic transmission problem. The inventor seems to feel that there is something essentially wrong with the use of gears, and that if they could just be abolished, all transmission difficulties would be eliminated.

The patent office files reveal an amazing amount of ingenious inventive effort that has been expended on



Transmission Development

ventional spur gear set. Latter ever, improvements having made er, and also lower in price.

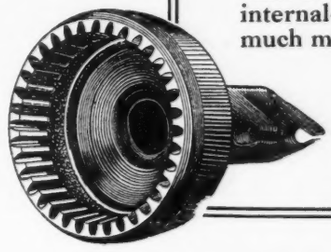
WHITE
Warner Gear Corp.

hydraulic transmissions, most of it highly impractical, and more complicated and expensive, by far, than the simple gear set which is to be displaced.

In between the mechanical gear shift and the hydraulic transmission, we have the automatic idea, in some cases called a torque converter. This may or may not make use of gear trains. There has been quite a development abroad along this line, and some in this country. They, however, seem to be about as far from a practical production device as the hydraulic transmission. Perhaps a simple, workable mechanism will be developed some time that will be automatic and possibly even hydraulic too, thus relieving the gear manufacturer of all his troubles. In the meantime, great progress is being made in improving geared transmission mechanisms and the gears themselves.

All of this inventive activity has served to pave the way in the mental attitude of transmission designers, automobile manufacturers and the buying public for practical improvements. It has stimulated the activity of the first, and has caused the latter two groups to demand and to be willing to pay for something better in the way of a transmission.

The outstanding development of the last three years has been the application of the internal gear to the automotive transmission. It has come in response to the demand for quieter gears, but it has been applied in such a way as to carry with it several other advantages. The general effect is to give a next-to-top speed that is almost as silent as the direct, with a sure and easy shift between these two speeds. The internal-geared speed, therefore, gets much more actual use than one would suppose, and it is gratifying to find an astonishing resistance to wear and breakage. It is quite usual on examination, after some 5000 miles of hard driving, much of it in hills and mountains, to find the teeth just beginning to polish nicely.



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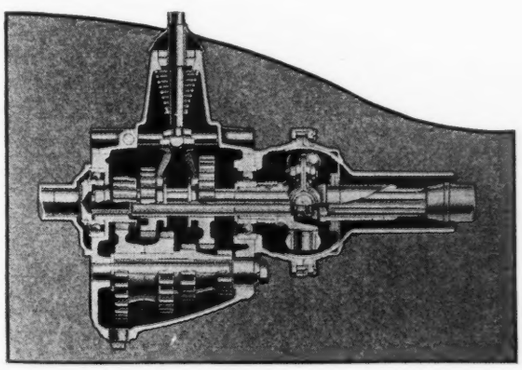

Perhaps the most important effect is that the internal geared transmission makes practical the use of a fast rear axle ratio, with a whole train of advantages coming from the consequently slower engine speed, such as lessened vibration, better general economy and longer life.

Three or Four Forward Speeds?

There has been much discussion as to whether the transmission should have three or four forward speeds. It is not the intention here to go into that phase of the subject, other than to say that while four speeds have very decided advantages in the flexibility and capacity of the car, it is also possible to get highly satisfactory results with three speeds, having an internal geared second. It is largely a question of the balance, in the particular installation considered, among the factors of engine ability, axle ratio and car weight, together with the kind of performance expected.

There seems to be no question but that four speeds are essential to the best results in truck and bus installations. The remarkable wear and strength factors of the internal gear make it ideal for this field, while the easy gear shift makes it particularly attractive to the driver.

The internal geared transmission is not as simple a design as the conventional and well-known spur gear type and there are many ways of combining the elements to produce the desired result. An immense amount of experimental work has been done and most of the de-

signs have had to be discarded, as there are far more ways of doing it wrong than of doing it right.

Either the sliding gear or the constant mesh principle may be applied to the internal elements. They may be placed ahead of the general gear train, or to the rear, or between the constant mesh front driving pair and the lower speed gears. The drive may go through the internal train for all geared speeds, or for one speed only, and so on to still other combinations.

Rigid Support Essential

The failure of many designs has been due to lack of rigid support in the internal train. For satisfactory results it is necessary that the mating gears be held very rigidly on their correct pitch circles. Mounting gears on long, unsupported shafts or undersized bearings has proved disastrous.

As the internal train is usually above the general oil level, special attention must be paid to oiling, and copious lubrication is essential. An oil pump or oil conveying means of some sort must be worked out. It is possible to do this in some instances without adding anything to the moving mechanism or complication of the design, but it must not be overlooked.

This carries with it the necessity for the use of fluid oils which will circulate, and not greases. This remark applies to conventional transmissions also, which should never be filled with heavy greases or compounds, but it is especially important with the internal gear transmission.

In this connection, it should be mentioned that the oil manufacturers still have a difficult problem to solve in the elimination of what is called "oil swish." The oil has a crackling sound that is very metallic, and which is present in spur gear transmissions to the same extent as in internals. The public, however, has come to expect a great deal of the internal gear, and while it is still audible, the situation would be improved if there were no oil noise.

The smoothness and comparative quietness of the internal gear, its strength and long life, combined with a sure and easy gear shift, give it such advantages that in some form it seems destined to displace the conventional spur gear set. The existing designs are constantly being refined and simplified, and experience is being gained in the peculiar problems of gear cutting and heat treating which will make transmissions of this type still better, and yet lighter and lower in cost.

While there has been all this activity in the way of new designs, the old spur gear has not been neglected. Transmissions of the conventional type today are smaller, more compact, stronger, quieter, more easily shifted and yet lower in price than ever before.

Some of this is due to concentration on large quantity production, but improved and more uniform steels, better forgings, improved heat treating methods, better gear cutters, more gear cutting knowledge, increased accuracy and better general design have all played their parts.

The gear manufacturer today must begin his inspection right at the steel mill, and there must be the very closest of cooperation between his metallurgical department and the mill. High carbon, alloy, oil quenching gear steels now predominate in the passenger car field. It is necessary to control their composition within very close limits, going to a point which some years ago would have been considered impracticable. The temperatures and all the handling operations must be very closely watched, if high-grade finished gears are to result.

From the mill the close supervision passes to the forge plant. For each size and shape of gear the right forging process must be adopted to give the best grain flow and the most favorable size and form of forging stock, determined upon long in advance. The upset forging process from round bars has proved highly satisfactory in many instances. It then becomes vital that the forging heats be kept within a rather narrow range, neither too high nor too low.

Given ideal forgings made from the best of steel, we are still far from good gears. Their proper normalizing and annealing are among the leading factors in securing a uniform, high quality gear product.

This has been best accomplished in quantities in a continuous operation furnace, so arranged that forgings of a given kind can always be stacked in the same manner. All the forgings receive heat uniformly, the temperature being accurately controlled and the time allowed in correct proportion to the weight of steel being treated. The heat is kept well above the critical temperature. The forgings then pass out into the air without being disturbed and are allowed to cool during a definite period of travel over to the next stage. This is an annealing furnace where they are brought up to slightly above the critical temperature. The second cooling takes place slowly in this furnace, which is long enough to permit the forgings to emerge at the far end, at a low red.

Same Microscopic Pattern

After this anneal, the forgings should then all show the same general microscopic pattern. They are in a satisfactory condition for machining, and the final hardening does not cause so much distortion. What distortion is still present is rather uniform, so that it is feasible to modify the gear cutters to make allowance for it. This method of handling produces results that could never be equaled with the old method of shoveling forgings into a furnace in a pile and then raking them out again on to another pile.

It was mentioned above that oil hardening gear steels are quite generally used in passenger car practice. Low carbon case hardening steels seem to have the field for truck type transmissions for the reason that their superior hardness gives a longer life from the standpoint of wear. There is, however, more fire distortion, causing more noise which is one of the principal reasons for using the oil-hardening steels in passenger cars, where noise requirements are more severe.

Truck transmissions, however, are employed in buses, where the service demands both quietness and long life. Also, general truck require-

"LOOKING back over the progress made by the gear industry, it is evident that the major steps forward have been made in recent years. The public demand for better and quieter gears has finally caused a concerted effort of reaching out for better things, and these things are now coming faster than ever before.

"The effort of specialized organizations devoted to transmission production, from research and design through all the problems of manufacture, is bringing results. Moreover, the real problems and the real advancement lie just ahead."

ments, especially in the speed truck class, are more particular than formerly. Furthermore, it is realized that with alloy case hardening steels, the physical properties are such that passenger car transmissions could be still smaller and lighter if they could meet the demand for quietness.

As an approach to this, many transmissions are now made having oil hardening gears which have received a short cyanide treatment. This leaves a surface that is cleaner of scale and there is a certain amount of skin hardness that improves the resistance to wear. It is, however, being found that with improved steels and better normalizing and final heat treating, there seems to be a possibility of approaching the quietness of the oil hardened gear with the case hardened. The goal is not exactly in sight, but the situation is hopeful.

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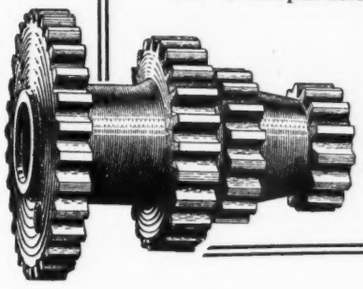


Along with improved metallurgy, there have come improvements in the gear cutting art. The makers of gear cutting machinery are producing more rigid and more accurate machines and putting more dependable accuracy in the cutters. Some of this has been brought about by the various devices that have been worked out for checking the tooth forms of gears and cutters. With these checking devices it has been possible to study the effect of very minute differences in form and to suggest modifications for increased quietness.

Laws Better Understood

While the fundamental laws of the involute tooth have not changed, they are better understood. More study is being given to unusual combinations leading to what might be called "freak teeth." There is a decided trend away from the stub tooth standard, especially for the front constant mesh pair and the intermediate pair, in favor of full height teeth. In some cases the addendum is even a little longer than for a full height tooth. With better heat treating the distortion is so controlled that it is feasible to run higher and to thinner tops than formerly.

Much work has been given to developing various systems by which there would be a minimum of two teeth in contact. Apparently this should divide the load better, making for both longer life and quieter operation. In practice this has not quite met expectations, yet it seems to be a move in the right direction and the idea will undoubtedly be developed further in the future.

The entire field of gear tooth literature is being carefully studied, and unusual forms and curves other than the involute are being rechecked in the light of the best modern practice, in the hope that something will be found that will permit of development into a better gear than we now know.

It is not enough to have a reasonably satisfactory set of gears. They must be properly housed and mounted. The use of aluminum for gear boxes has about passed out. This is not so much a matter of cost, but it has been proved that the gears run best in an iron case, having fairly heavy walls, rigidly braced. These iron gear boxes must be very accurately machined and the shafts must be heavy for rigidity, and parallel. All parts must be fitted with the minimum clearances that will permit of free running and sufficient lubrication. These close clearances constitute one of the reasons for the fluid oil lubrication mentioned previously. The sliding gears must fit on their splined shafts with practically no perceptible shake, and yet their pitch lines must run true with the bearings on the shaft.

It will be sensed from the foregoing general survey that acceptable automobile transmissions can no longer be produced on general machine tools in gear departments such as were common a few years ago. It is also neither practical nor satisfactory to have one concern produce the housing and mounting parts and some other concern make the gears. The whole job must be handled as a unit, by a specialist who can concentrate on the transmission and all its parts, including the gears as a complete assembly. For best results much of the equipment must be single purpose machinery, designed for the particular job it has to do. Such equipment is only economical where there is a large volume of material flowing through and with a certain amount of standardization of design.

Developments Coming Fast

Looking backward over the progress made by the gear industry, it is most evident that the major steps forward have been in recent years. The public demand for better and quieter gears has finally caused a concerted effort of reaching out for better things, and these things are now coming faster than ever before.

The entire effort of separate specialized organizations, devoted to transmission production, from research and design, through all the problems of manufacture, is producing results. Moreover, the real problems and the real advancement lie just ahead, with the gear specialist bending every effort to speed the day of realization.

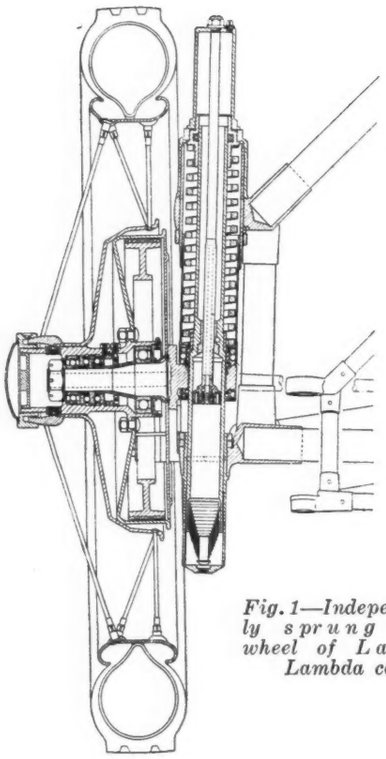


Fig. 1—Independently sprung front wheel of Lancia Lambda car

Engineers Seek to Improve by Independent

In Europe, especially, much development work along this line has been done with satisfactory results. Two chief advantages are reduction of unsprung weight and elimination of wheel wobble. Tire wear also lessened.

FOR some years past a good deal of interest has been evinced in Europe in the subject of independent springing for each wheel of a car. Many of the novel and unusual designs of car exhibited at the Continental shows of the last two years were equipped with this form of springing. The practice seems to have been carried furthest in the succession states of the former Austro-Hungarian Empire, where at least four long-established firms are manufacturing cars having independently sprung wheels.

As the subject is a rather new one in this country, it may be as well to explain what is meant by independent springing.

In the conventional car, when one of the road wheels strikes an obstacle and is compelled to pass over it, not only the chassis spring adjacent to that wheel, but the one on the opposite side as well, is compressed, though the degree of compression naturally is considerably greater in the case of the nearby spring. Moreover, the front axle with the two wheels at its opposite ends forms a more or less rigid assembly which is capable of vibration in a vertical plane by alternately compressing the tire and the chassis spring on each side.

In a car with independently sprung wheels these two characteristics are absent. Perhaps no better exemplification of the principle of independent springing could be found than the Kamm (or S. H. W.) car to which reference was made in an article on Front Drives in these columns about a year ago. This car has a body built up of shapes and sheets of duralumin in such a manner that is possesses great rigidity. At or near each corner of this body is secured a bracket comprising a vertical guide in or on which a stub axle is adapted to slide vertically up and down, the body being supported on this stub axle through the intermediary of a coiled spring. It would be an exaggeration to say that when one of the road wheels strikes an obstruction the other wheel and the spring near it are not affected at all. The effect of the blow is not absorbed entirely by the spring but is in part communicated to the body, and through the body to the spring and the wheel on the opposite side, but not to nearly the same extent as if both wheels and both springs were connected by a rigid axle.

Advantages of Independent Springing

The question now arises as to what is the exact advantage of such independent springing. The springs are provided to cushion the blows due to road irregularities and it would seem to make little difference whether any such blow is divided in a certain proportion between the springs at opposite sides of the chassis or whether it is taken entirely by the nearby spring. A good deal of sophistry has been broadcast in connection with this subject, but in the writer's opinion there are just two advantages resulting from this

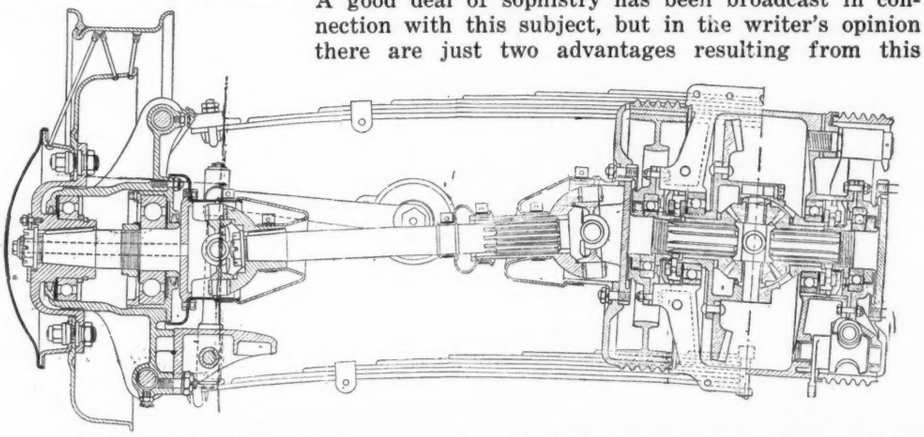


Fig. 3—Cottin-Desgouttes rear axle with leaf-spring-type carrying member

Riding Qualities
Springing

By
P. M. HELDT

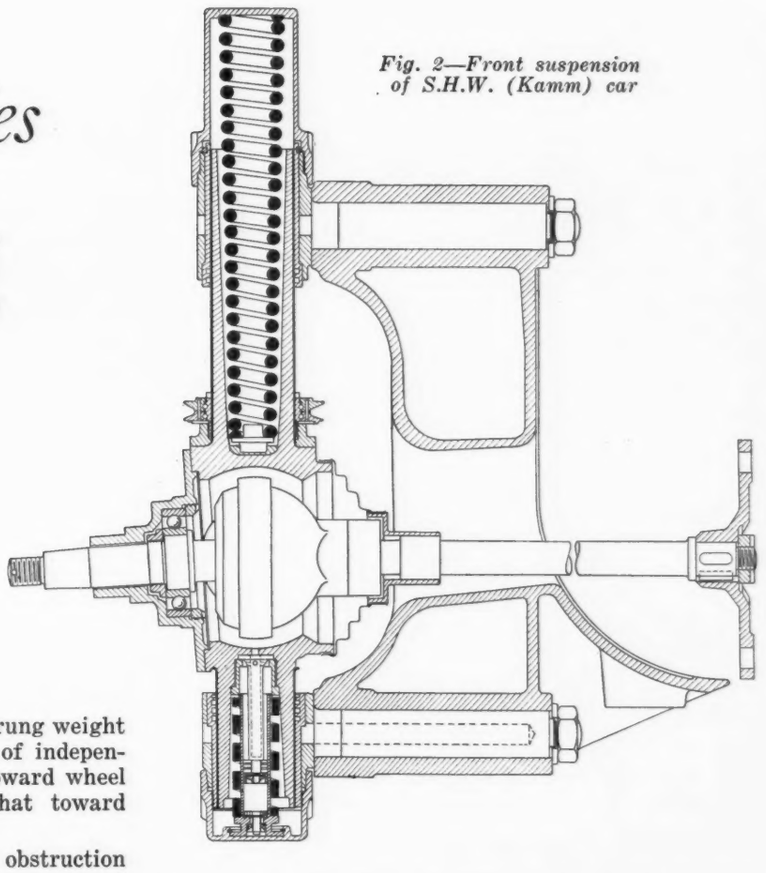


Fig. 2—Front suspension of S.H.W. (Kamm) car

method of suspension, namely, that the unsprung weight is materially reduced and that in the case of independently sprung front wheels the tendency toward wheel wobble is eliminated (and incidentally that toward shimmy can be more readily dealt with).

When one of the road wheels strikes an obstruction it is given a vertical acceleration, and an amount of energy is stored up in it which is proportional to its weight and to the square of the maximum vertical speed attained by it. But it is not only the wheel with its tire which is subjected to vertical acceleration. All of the other unsprung parts, which in the conventional design include the axle and the bulk of the weight of the chassis spring, also are given a vertical acceleration. Through the chassis spring this stored energy is transferred to the body, and each time one of the wheels passes over an obstruction the body also is thrown upward, though with a slight lag.

The upward movement of the wheel is determined chiefly by the height of the obstacle, but the following upward movement of the body depends not only on this but also on the relation of the body weight to the wheel weight or, more correctly, the unsprung weight. If the unsprung weight is very small, then the energy stored up in it by reason of its upward motion also is small. The upward speed which must be attained by the body in order to absorb this store of energy will therefore be small, and it will be the smaller the greater the weight of the body. Thus the vibration (or the jouncing) of the body will be less the smaller the unsprung weight and the greater the sprung weight, and engineers have always endeavored to make the ratio of sprung to unsprung weight a maximum.

Eliminates Wheel Wobble

A car with relatively small unsprung weight not only rides well but it also keeps the road well. Its wheels are not thrown into the air in hitting obstructions but are constantly kept in contact with the ground, because of the great inertia of the weight supported by the springs, and this tends to reduce tire wear.

That independent springing of front wheels must prevent wheel wobble is more or less obvious without argument. This wheel wobble consists of a periodic rocking motion of the front axle and wheel assembly around a horizontal axis through the middle of the axle. Since with independently sprung wheels there is no such assembly there can be no wobbling. Shimmy, moreover, which consists of a periodic rocking motion of the two front wheels around their knuckle pins, is also more readily combatted, since with the elimination of the front axle the tie rod also is usually eliminated and the two wheels no longer are directly connected and cannot so readily vibrate in unison.

Classification of Designs

While the method of mounting stub axles on brackets secured to a metal body is the extreme case of independent springing and probably achieves its object most completely, there are several other possible methods. In fact, four different methods may be distinguished, as follows:

1. Vertically sliding stub axles.
2. Stub axles pinned to the ends of transverse leaf springs.
3. Driving axles with tubes capable of a vertical rocking motion relative to the center housing.
4. Stub axles mounted on levers fulcrumed on the vehicle frame, these levers being cushioned by steel or pneumatic springs.

Of the first type there are only few examples. The pioneer in this class, and apparently the only representative of it in actual production, is the Lancia Lambda, the front suspension of which is illustrated in vertical section in Fig. 1. In this construction, the so-called axle end or steering head is supported from the car frame and radiator shell by means of steel tubular mem-

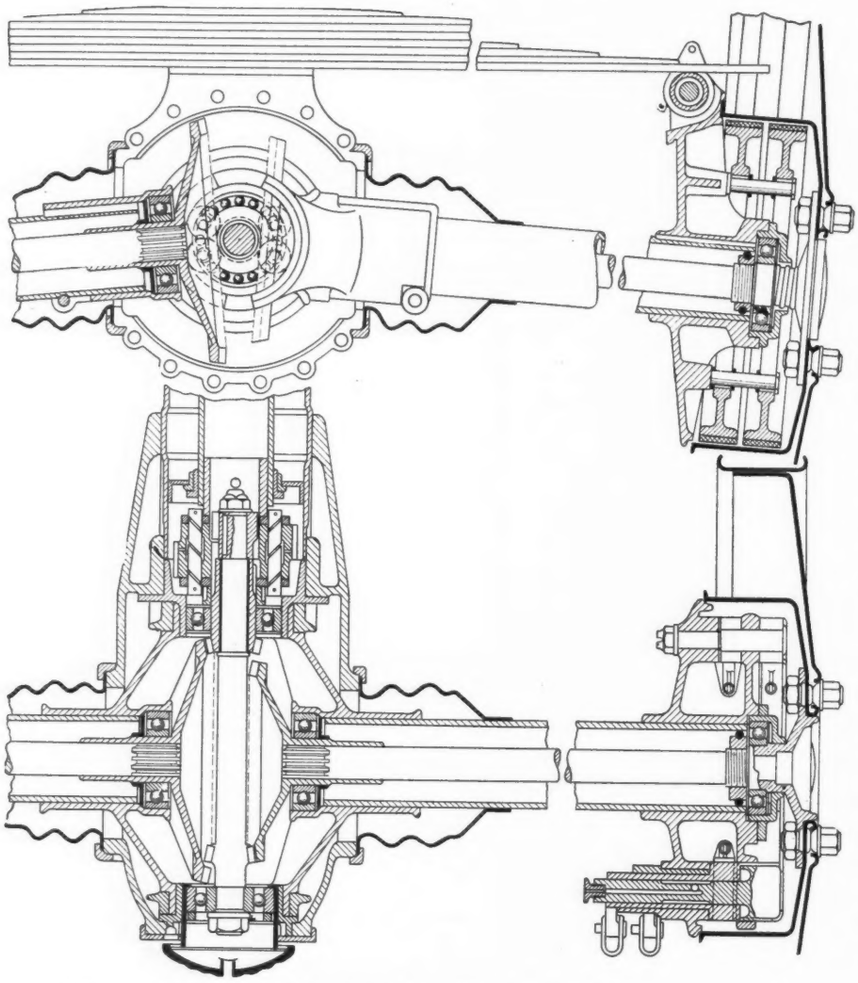


Fig. 4—Vertical and horizontal sections through Tatra rear axle with swinging axle tubes

bers. One tube at both top and bottom lies in the vertical plane through the front wheel axis, and an additional tube at both top and bottom runs toward the rear, the lower one of this pair being secured to the car frame. This tubular trussed construction evidently assures great rigidity with comparatively small weight. A long tubular knuckle pin is used, which is capable of both a rotary and a sliding motion in the steering head.

The weight of the forward end of the car is supported on the steering knuckle through a coiled spring surrounding the tubular knuckle pin, while at the lower end of this pin there is a volute-type of steel spring which cushions the rebound. An hydraulic shock absorber is incorporated in the design. Within the lower part of the hollow knuckle pin there is a stationary piston, and as the knuckle pin moves up and down with the spring action, the space between this piston and a neck in the pin in which the piston rod has a bearing is varied, and oil is forced through a central hole through the piston rod from the space referred to to a space in the upper part of the knuckle pin, and vice versa. The piston rod is anchored in a cap over the steering head. This car was first exhibited at the Paris Show of 1922 and has been in production ever since, being now in production also in this country. The rear suspension is conventional.

Two other designs employing independently sprung front wheels with the steering knuckles having an up and down sliding motion have been brought out in Europe in recent years. Both of these, in contrast to the Lancia, have front-wheel drive. One is the S. H. W. designed by Dr. Kamm of the Adlershof Flying Field. A drawing showing a section through the steering head is reproduced herewith (Fig. 2). It will be seen that the drive to the front wheel is through a universal joint whose center lies in the knuckle pin axis. In an earlier design this was through two pairs of bevel gears, the two intermediate gears being connected by a short shaft coaxial with the knuckle pivot, one of the gears sliding on splines on the shaft with the spring action. There is only one coiled spring in this design, above the wheel axis, a shock absorber of the hydraulic type being located in the axle end below the level of the wheel axis.

The other representative of this class is the new car of Sensaud de Lavaud, the front axle construction of which was shown in our issue of Nov. 5, last. This car has a front axle that is swiveled at its center on a horizontal trunnion on the car frame. Each front wheel is independently sprung on the end of the front axle by means of a stack of rubber blocks separated by metal washers.

The type of construction in which the axles are replaced by an assembly of transverse springs, or by springs and links, is not unknown in this country. A number of experimental cars of this type were built, and one of them was to be produced on a large scale in Buffalo during the inflation period which followed the war. It is more than likely that the unchecked stock promotion which accompanied the development of this and one other similar design proved a setback which will not be overcome for a long time. The excellent riding qualities of this type of vehicle were a great asset to the promoters, as any layman could appreciate them when given a demonstration.

Effect on Wheel Tread

Naturally, a number of new problems arise when a rigid axle is dispensed with. One of the objections that has been raised against this design is that the wheel tread is changed by the spring action and that as a result there is transverse slippage of the tires on the ground, and increased tire wear. There must, of necessity, be some change in the width of the tread with spring deflection, but if the springs are so designed that they are practically straight when under normal load, this change will be very slight, especially in the case of the front tread, since the front springs have a more limited range of action than the rear ones. With balloon tires this change in the tread should be entirely absorbed by the lateral flexibility of the tires and not give rise to any additional tire wear. Tire wear, as a matter of fact, is dependent to a large extent

upon the amount of unsprung weight carried. With the lower unsprung weights of this construction there should be less hammering of the tires and less slippage due to temporarily leaving the ground, and longer tire life might be confidently expected. Probably a more serious result than the effect on tire life would be the alternating thrust loads on the rear axle bearings due to this constant change in tread.

Another problem in connection with spring-type axles consists in securing sufficient rigidity to enable the axle to withstand the various forces to which it is subjected. Of course, since the center housing is rigidly supported on the chassis frame, the reaction from the driving torque is taken on the frame and does not subject the axle to any stresses. This reaction originates at the bearings of the driving bevel pinion, mounted in the center housing, and is transmitted from there to the car frame.

Similarly, if brake drums are mounted on the shafts projecting from the center housing on both sides, instead of directly on the wheels, the brake supports will be on the center housing and the brake torque reaction will be transmitted to the car frame directly. However, the axle must take the driving thrust and the brake drag. If wheel brakes are used the spring structure replacing the axles must take the braking torque and has to be designed accordingly.

Usually either three or four springs are used, spaced at considerable distances horizontally and vertically. Obviously this type of construction is best suited to light and moderately powered cars, although it is being used on the Itala racer with front wheel drive, in the case of which the driving and braking torques must be quite heavy. The use of radius rods from the stub axles to the frame would help to carry the torque loads but would add complication.

In a rear end in which the rigid axle is replaced by leaf springs the unsprung weight is certainly greatly reduced. As already pointed out, the center housing with its differential and driving gears, which accounts for a very considerable fraction of the weight of the rear axle assembly, is mounted on the car frame and is therefore sprung weight. No axle tubes are employed and this part of the unsprung weight in a normal car is therefore eliminated. Of the ordinary semi-elliptic springs about three-fourths of the weight is unsprung because the thick center portion is carried by the axle while the thin ends are connected to the frame. In the case here under consideration the arrangement is reversed and the thick center portion is secured to the frame and therefore sprung, while the thin ends are connected to the stub axles and unsprung. Therefore, in this case three-quarters of the spring weight is sprung as compared with one-quarter in the standard design. Similarly, the axle shafts, which in the standard design are completely unsprung, in this design are sprung to the extent of about 50 per cent, their inner end being supported by the chassis.

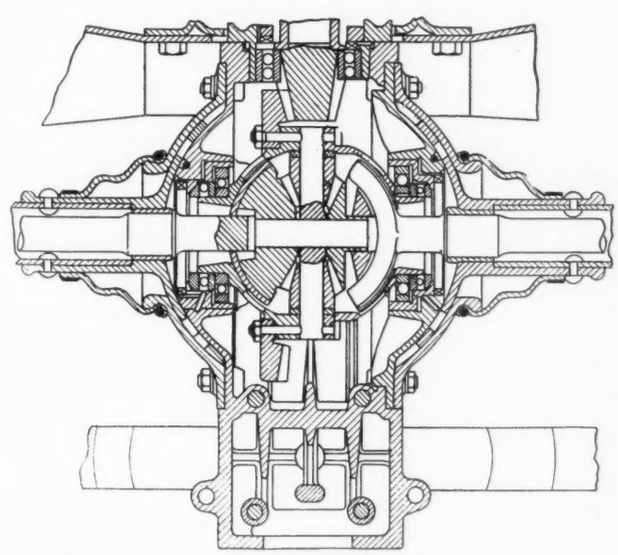


Fig. 5—Horizontal section through center housing of Steyr rear axle

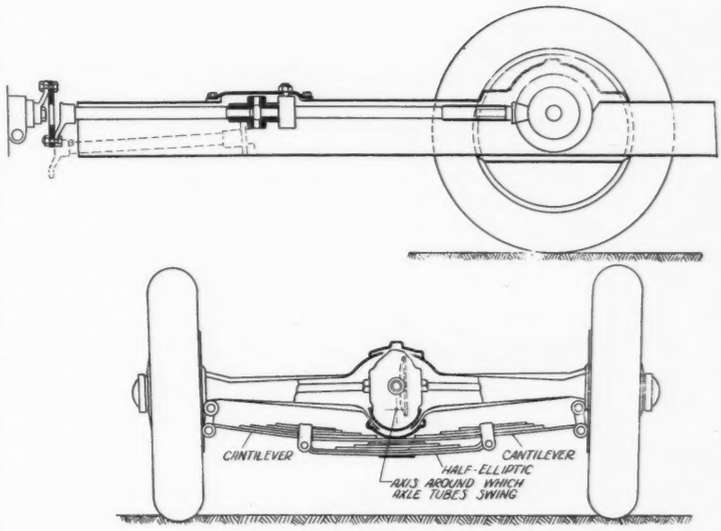


Fig. 6—Diagrammatic views of the Austo-Daimler rear axle with swinging axle tubes

Spring-type of Rear Axle

An example of a chassis in which the axles are replaced by cross springs is the Cottin-Desgouttes, the rear axle of which is shown in sectional elevation in Fig. 3. There are four quarter-elliptic springs on each side of the center housing, bolted to spring pads cast on the housing. At its outer end the master leaf of each spring is clipped to a separate spring eye. These spring eyes are pivoted on brackets formed integral with what may be described as a false rear wheel hub, in which are mounted two ball bearings that support short driving shafts to which the hubs of the driving wheels are keyed. The axle shafts both consist of three parts, one carrying one of the differential side gears, another carrying one driving wheel, and the third intermediate between the first two and connecting to each of them through a universal joint.

When we compare this construction with a well known American car in the low-priced class, in which there is a single transverse spring, we cannot fail to reach the conclusion that the construction is somewhat complicated, with eight springs and six driving shafts at the rear, and with four universal joints, each of which must transmit one-half of the rear axle torque, as compared with a single such joint in the American car referred to, which, moreover, has to transmit only about one-quarter the rear axle torque.

A front-driven car in which the frame and body are

supported on stub axles through the intermediary of transverse springs is the Voran built in Berlin. The differential and driving gears are contained in a central housing suspended from the car frame. Two quarter-elliptic springs are anchored to the housing, one on each side, and a stub axle is secured to their outer ends by spring bolts. A feature of this design is the use of two universal joints at each wheel, whereby any tendency to periodic speed variations of the wheels when they are swung from their straight-ahead position is obviated. The stub axles are braced to the frame by radius rods, which is necessary because only two springs are used on each side and the brake drums are mounted on the wheel hubs, so that the reaction to the brake torque must be taken by these axles. A car known as the Tracta is being built in France on the same principle.

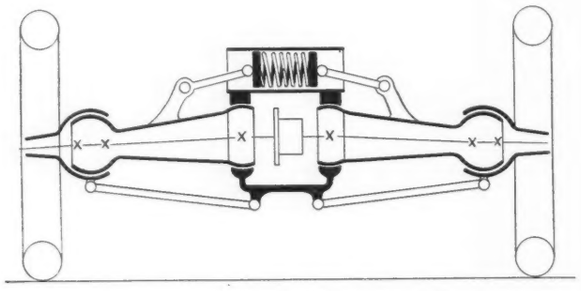


Fig. 7—Diagram of Bucciali front driving axle

As already pointed out, the most popular method of independent springing of the road wheels consists in so arranging the axle tubes that they can swing around a horizontal axis through the center of the center housing or slightly lower. This plan, of course, is used only in connection with driving axles. Among cars with such swinging driving axles are the Rumpler in Germany, the Bucciali in France, the Tatra in Czechoslovakia, and the the Steyr, Austro-Daimler and Austro-Fiat in Austria.

Tatra Swinging Rear Axle Tubes

The Tatra is a light passenger car which is characterized by a tubular backbone type of frame and independently swinging rear driving axles. Vertical and horizontal sections through the rear axle are shown in Fig. 4. A hollow propeller shaft is used, inclosed within the frame tube, which carries at its end the pinion carrier of a differential of the spur pinion type. The two pairs of spur pinions in the differential mesh respectively with two spur gears, of which one is fastened on a central shaft and the other is mounted free on this shaft and is integral with a bevel pinion meshing with a bevel gear on one of the axle shafts. The central shaft also carries a bevel pinion which meshes with a bevel gear on the other axle shaft. In order to avoid interference, the two pairs of bevel gears have different diameters, but both have the same ratio.

Each of the axle shafts is surrounded by a tube which at its inner end carries a fork, the ends of the prongs of which are in the form of cylindrical sectors which have a bearing between an inner cylinder fastened into the center housing and an outer ring slipped over them, this outer ring being provided with a radial flange to increase its rigidity. There are comparatively large openings in the center housing at both sides through which the axle tubes extend and which are closed by leather boots. The single spring is secured to the top of the center housing and its free ends bear each against a roller carried at the top of the brake carrier. The forks at the inner end of the axle tubes evidently take care of the driving thrust, brake drag and brake torsion on the tubes.

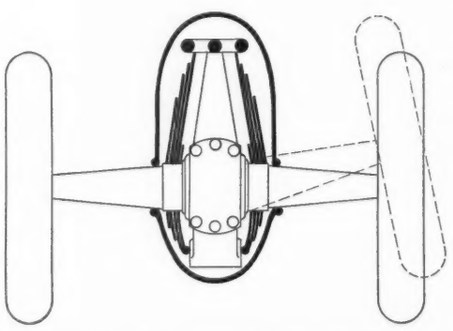


Fig. 8—Fiat patent independent rear wheel springing

Steyr Construction

Another car with swinging driving axles is the Steyr, manufactured in Austria. This has the usual drive by a single pair of bevel gears with the driven gear secured to the housing of the differential. But the axle shafts, instead of being fastened into the differential side gears by keying or splining, are connected thereto by means of a peculiar form of universal joint. Each side gear is formed with driving keys on its back which engage into a slot in an intermediate piece. This intermediate piece has slots at right angles with each other in its opposite sides, the same as the center piece of a Hookham joint. Into the slot on the outer side of this intermediate piece engages a fork formed on the inner end of the axle shaft. Thus there is a universal connection between each differential side gear and its axle shaft. The outer end of the axle housing in this case is connected to the vehicle frame by a member which takes both torsion and thrust.

At the European automobile shows last fall the Austrian Daimler Motor Co. showed for the first time a new 3-liter car with tubular steel backbone instead of the conventional chassis frame, and with independently sprung rear wheels. Referring to Fig. 6, it will be seen that a steel tube of about 6 in. diameter extends forward from the center housing of the rear axle to a point immediately back of the transmission, where it has a forked pressed steel member in halves clamped to it. The prongs of this fork extend along the sides of the engine and carry the latter, and they in turn are supported on the front axle through the intermediary of the usual front half-elliptic springs.

The rear axle tubes are tapered and ribbed and they carry a segment of a spherical surface at their inner end. They are so supported inside the center housing that they are capable of a swinging motion in a vertical plane. The arrangement of the rear chassis springs is rather different from that of other cars with independently sprung wheels. A half-elliptic transverse spring is secured with its center portion underneath the center housing. To the ends of this spring are clipped the center portions of two half-elliptic transverse cantilever springs whose inner ends are pivoted to the center housing and whose outer ends are shackled to the outer end of the axle tubes. There are no radius rods or braces and moments due to one of the rear wheels striking an obstruction evidently are taken up at guides or supports for the sectors formed on the axle tubes, at the front and rear of the center housing.

A feature in respect to which the Austro-Daimler differs from other cars with swinging rear-axle tubes is that the axis around which these tubes swing is not on a level with the axis of the differ-

ential side gears, but lower. The object in thus lowering the axis of the swinging motion is to reduce the variations in the tread of the rear wheels due to spring action.

A very peculiar front axle design is being used on the Bucciali car which was exhibited at the Paris Salon of 1926 for the first time and in a slightly modified form at last year's Salon. The car has front wheel drive and employs the Sensaud de Lavaud automatic transmission. The differential gear with its driving member is located in a central housing mounted on the chassis frame. As shown in Fig. 7, two axle tubes have such a support in the side walls of this housing that they can swing in a vertical plane. Each axle tube at its outer end is developed in the form of a ball which is surrounded by a socket forming part of the steering knuckle. This ball and socket joint at the end of the axle tube takes the place of the conventional steering knuckle joint. Ordinarily the motion of the steering knuckle around the axle-end ball is confined to a horizontal plane by a tie rod with ball and socket joints which extends from the central housing to the lowest point of the socket on the steering knuckle. However, when the wheel at the end of the axle tube hits an obstacle the axle tube will describe a motion in a vertical plane, compressing a coiled spring in a spring-holder directly above the central housing. This upward-swinging motion of the axle tube will be accompanied by a motion of the ball and socket joint at the end of the axle, to maintain the knuckle spindle in a horizontal or nearly horizontal position.

Fiat Vertical Rear Springs

A rather peculiar form of independent springing for driving axles of the swinging type has been patented by the Fiat firm, but does not seem to have been applied to cars in production as yet (Fig. 8). Leaf springs are used, and are anchored to the half axles near their joints with the center housing, while their ends are connected to the vehicle frame. Preferably the springs are shackled to an arm extending vertically from the center housing, which results in a very narrow construction that permits of very good streamlining. It would seem that the scheme were intended for racing cars.

In the latest Rumpler design, which has front drive together with independent suspension of the wheels, two quarter-elliptic springs extend laterally from the frame on each side at the front, their ends resting on rubber blocks held in spring shackles of peculiar design, as shown in Fig. 9. The two shackles have bearings on the end of a short bar which rests with its middle on top of the axle housing. The springs are not utilized for pulling the load behind the front axle, this function being performed by the axle housings, which are suitably braced for the purpose.

A very peculiar arrangement of the chassis springs is found on the Harris-Leon Laisne car which was one of the novelties of the Paris show of 1927. As illustrated in Fig. 10, use is made of two concentric coiled springs which are inclosed in the ends of the tubular frame side bars, the latter being 3⅛ in. in diameter. A cross-member of the frame, also tubular, forms a pivot for two bell cranks whose longer arms support stub axles on which the steering knuckles are pivoted in front and on which the wheels have their bearings in the rear. The short arm of each bell crank passes through a slot in the wall of the frame tube and presses against a button or mushroom which is supported by the coiled springs. At the forward end of the chassis frame tube there are means for adjusting the spring. This, of course, does not alter the so-called rate of the

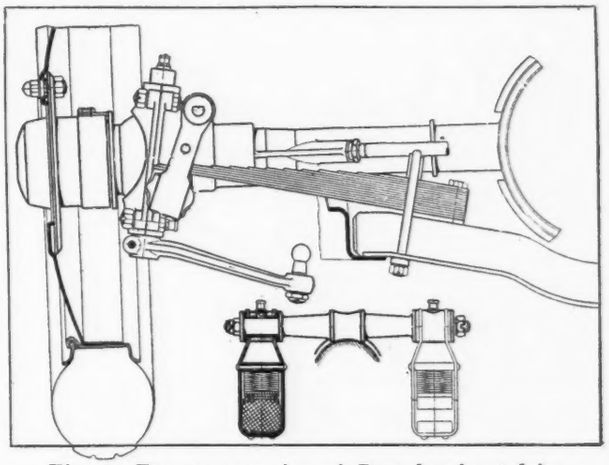


Fig. 9—Front suspension of Rumpler front-drive car

spring but is equivalent to raising the support of an ordinary semi-elliptic spring on the axle. The member against which the short arm of the bell crank bears is really supported between two springs pressing it toward the rear and one spring pressing it toward the front. This latter performs the function of a reverse spring and prevents excessive rebound. The leverage of the bell crank, that is, the ratio of the lengths of its two arms, is 4 to 1. Hence the coiled springs within the frame tube must support a load equal to four times the load carried on the front wheel and they are exceedingly stiff. In fact, a pressure of about 6500 lb. is required to close up these springs solid. Descriptions of this suspension that appeared in European papers stated that the rebound is damped by an hydraulic type shock absorber also contained within the chassis frame tube.

Records of trial runs made with this car over rough roads stress the ease of riding and the comparatively high speeds it is possible to maintain on rough roads. Obstacles up to 6 in. in height are said to produce hardly any vertical motion of the body, and even a test chassis without upholstery rides comfortably over pavements in a bad state of repair.

The plan of independent springing of wheels has been applied also to commercial vehicles. Faudi in Germany, who has designed a number of automobile parts that have achieved a considerable degree of popularity, about two years ago developed a pneumatic springing system which renders each wheel independent, and this was applied to a Daag bus that was exhibited at the commercial vehicle show at Cologne in 1927.

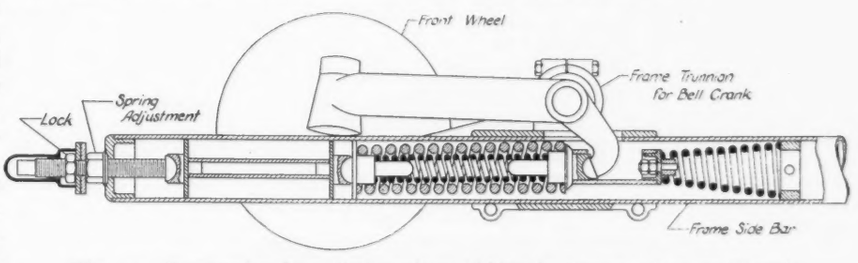


Fig. 10—Suspension by coiled springs hidden in frame tubes, on Harris-Leon Laisne car

In large commercial vehicles the unsprung weights are exceedingly heavy and the wear and tear on wheels and tires are correspondingly great, not to speak of the wear on road surfaces. Any decrease in the unsprung weight should increase tire life, and if the saving is obtained by mounting the axle on springs, it should permit of cutting down on the weight of the wheels.

Fig. 11 illustrates the Faudi pneumatic suspension as applied to the Daag bus. A double reduction final drive is employed and the housing inclosing the driving and differential gears is mounted on the bus frame. The stub axle on which the wheel is carried forms part of a crank having bearings on the chassis frame, a long plain bearing just inside the frame side member and a double row ball bearing near the center of the frame. Between these two beearing supports a yoke is keyed to the crank axle, by means of which the moment on the crank due to the reaction of the ground on the rear wheels is taken on a pneumatic cylinder. The stub axle is hollow and the wheel hub is mounted on the outside of it as in a full-floating axle. Transmissions from the differential side gear to the wheel hub is through three short shafts and two universal joints. The same method of suspension is used for the front wheels but in that case the stub axles have the steering knuckles pivoted to them.

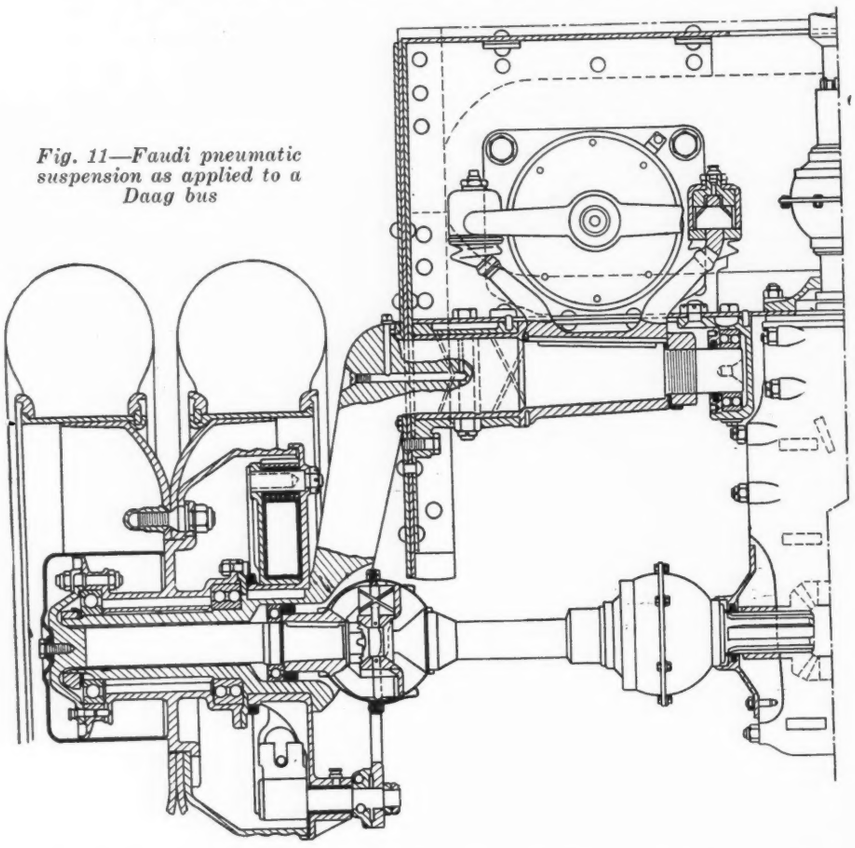


Fig. 11—Faudi pneumatic suspension as applied to a Daag bus

German Passenger Car Tests

THE General German Automobile Club, which, as announced in our issue of April 28, planned very elaborate tests of all types of motor vehicle from motorcycles to buses, was able to carry out only a part of its program according to schedule, and the motorcycle, truck and bus trials were postponed until fall. In the trials of passenger cars, which took place May 1-10, 32 cars took part, including a number of Fords.

In one of the acceleration tests, in which the driver could change gear as desired, the Ford cars made the best showing. Competing cars were divided into classes according to seating capacity. In the four-passenger class the best acceleration records were made by Ford and Adler; in the six-passenger class by Brennabor.

Minimum Speed in High

Another test was with relation to minimum speed in direct drive. The best results in this test were achieved by a Steyr and an Adler in the two-passenger class (3.50 and 4.06 m.p.h.) while in the four-passenger class the lowest speed was made by an Adler, viz.: 2.12 m.p.h. and in the six-passenger class by a Brennabor 2.44 m.p.h.

In the brake tests the drivers were required to apply their brakes while going at 60 km. (37.3 m.p.h). The shortest stop was made by an Adler Standard Six in 52.5 ft., while several others stopped in 55.75 ft.

Another feature of the trials was a hill climb over a 2.5 mile course in the Silesian Mountains. Here the Fords showed to advantage. Most of the cars carried skid chains in this test, but the Fords did not. Only those cars that ascended the hill in a time not exceeding that of the winner in their class by 25 per cent were "classed." In the four-passenger class only two Fords and one other car were classed. Some of the low-powered cars, including the Hanomags with only 30.5 cu. in. displacement, the Dixi (Austin license) with 46 cu. in. displacement and three 91½ cu. in. Brennabors did not succeed in making the hill. Help from outsiders was prohibited, but in the case of some of the smaller cars the passengers did their best by getting out and pushing at particularly difficult points, and in one instance a car unexpectedly gained speed while being pushed so that the passenger was unable to get in and remained behind.

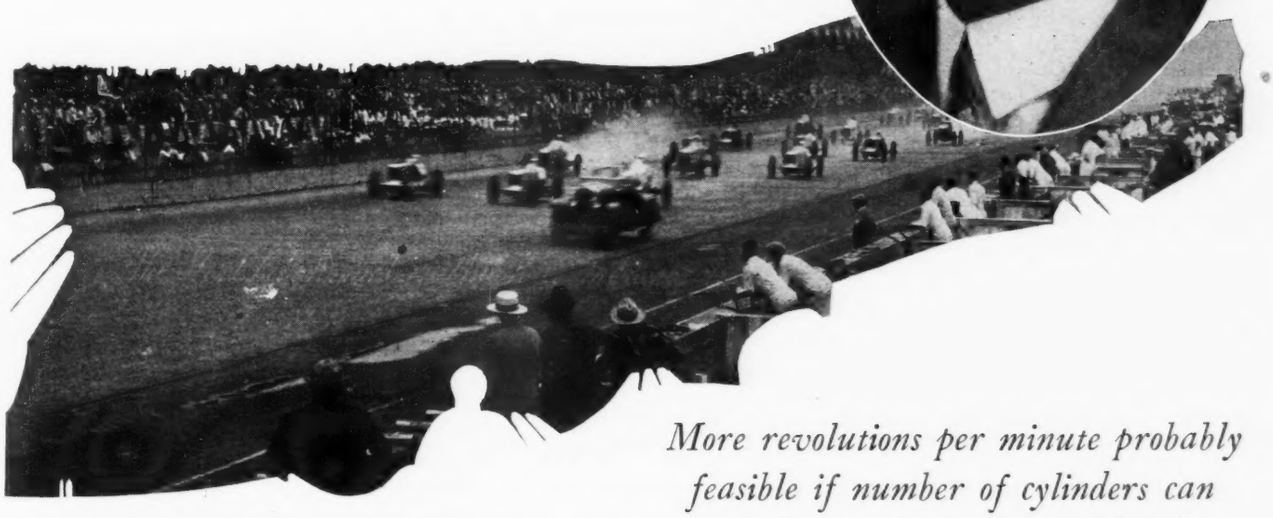
The contest was being opposed by a large section of the German industry, partly, perhaps, because altogether too many contests are being organized, and also because they looked with some suspicion on this new form of competition. Among the competing German firms, Adler and Brennabor, both of which had quite a number of cars in the contest, made the best showing. The honorary prize of the Prussian Minister of Transport for the greatest number of points in any division was won by Prof. Gabriel Becker of the Charlottenburg Technical College, driving an Adler Standard Six. Professor Becker also won several other prizes.

THE Bureau of Mines, Department of Commerce, has published a report concerning A Rapid Corrosion Test for Gasoline, by H. P. Rue, associate refinery engineer of the Bureau.

Inertia Forces an Obstacle to Higher

Racing Car Engine Speeds

By COL. W. G. WALL
President, Society of Automotive Engineers



More revolutions per minute probably feasible if number of cylinders can be increased, the bore reduced and lighter metals utilized for moving parts.

THE other day I heard an engineer remark that we probably had reached the limit of speed for our racing car engines—that in the future we would have to look to other means to get more horsepower out of them.

Was he right?

Increasing the speed has been a comparatively easy way of securing more power out of a given displacement, the horsepower being theoretically proportional to the speed (that is, the number of revolutions). Of course a certain amount of ingenuity has had to be used and considerable work done to get engines to run at the present high speeds.

In 1912 the Indianapolis 500-mile race was won by a car with an engine of 490 cu. in. displacement, which turned over at a maximum speed of about 2200 r.p.m. The fast cars in the 1927 race had a piston displacement of 91 cu. in., less than one-fifth the size of the larger one, with a maximum engine speed of about 7500 r.p.m.

The former engine developed about 100 hp. maximum, or about 0.204 hp. per cu. in. displacement, while the latter developed 160 hp. or more, or about 1.75 hp. per cu. in. displacement.

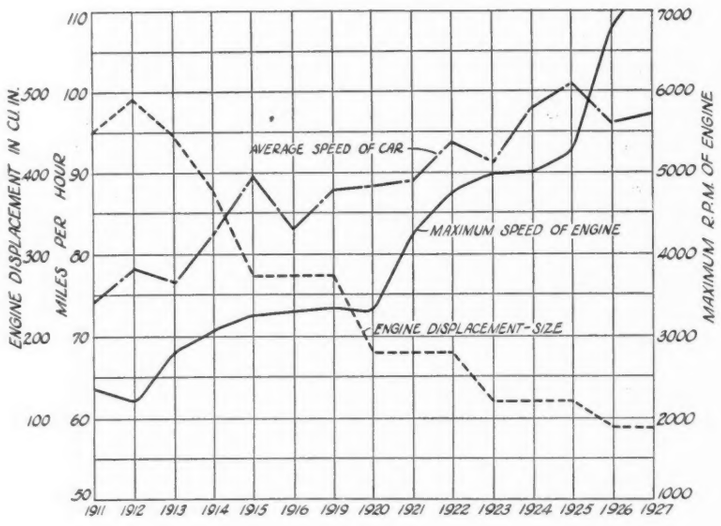
Less than 15 years ago 3000 r.p.m. for an engine was considered extremely high speed and many engineers thought even that speed was too fast for an engine to withstand. Today there are a number of passenger car engines that will turn up to 4500 r.p.m., and racing car engines do up to 8000 r.p.m. I understand a certain foreign manufacturer has developed a reciprocating engine which turns over at 11,000 r.p.m. It thus seems that the limit of speed may be very much higher than we today can well imagine.

There is a practical limit, however, to all engine speed and it has been necessary, in order to make the reciprocating parts sufficiently light, to make the bore of the cylinders smaller and the pistons lighter. Alloy steels and aluminum alloys have played an important part in this work, especially aluminum pistons. and in some cases duralumin connecting rods.

It has been necessary to develop high pressure oiling systems, to lubricate not only the bearings which are revolving so fast, but also the cylinders, so as to cut down the great amount of friction there would otherwise be; remember that the pistons are traveling through the bore of the cylinders in these high speed engines at the rate of about a mile a minute.

The high speed engine of today is due largely to the supercharger. In order to run up speed, it was necessary to cut down the weight of the reciprocating parts. One of the easiest ways of doing this was to cut down the bore of the cylinders, but this also meant that the size of the valves had to be cut down, so that there was a point reached in speed where it seemed impossible to fill the cylinders with gas. Therefore, the volumetric efficiency dropped. This has been remedied to a great extent by the use of the supercharger, forcing the gas into the cylinders.

The supercharger for racing car engines is having a great amount of development work done on it. Most of this is on the centrifugal type, which is generally geared to the engine with a ratio of about 4½ to 1, thus making the supercharger revolve on an engine running at 8000 r.p.m. at a speed of 36,000 r.p.m.—some of them as a matter of fact operate faster than this.



These curves, based on the performance of the winning cars in the Indianapolis 500-mile race since 1911, show how the displacement size of engines has been reduced and how the average speed has gone up. Also how engine speed has increased with the decrease in displacement. Car speed is the average during the race and not the maximum

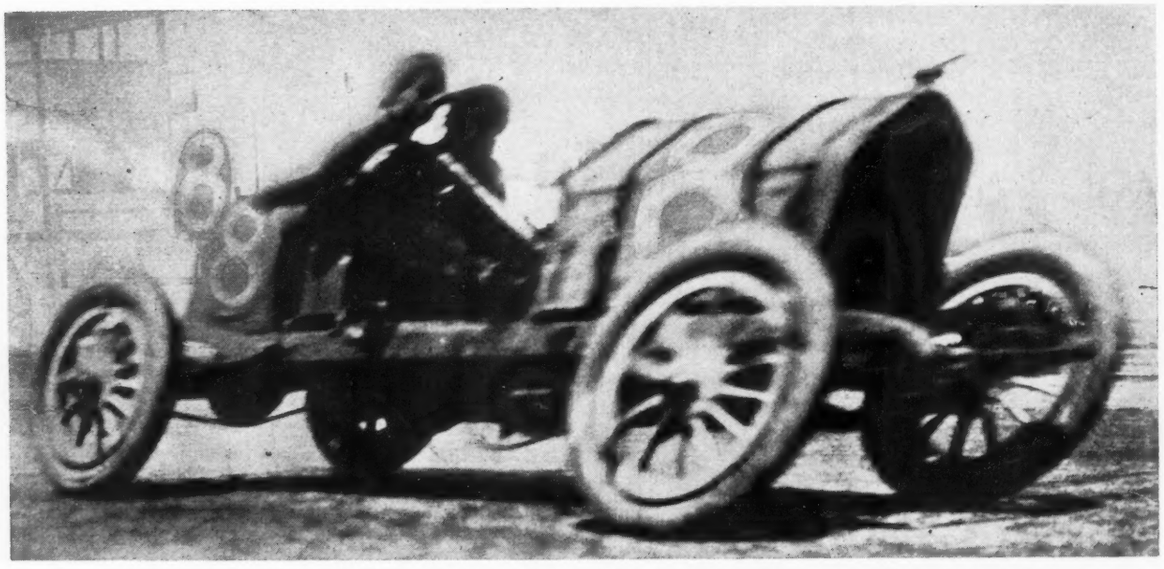
Most of these high speed engines have eight cylinders. This has helped some, for by increasing the number of cylinders it has allowed the bore to be made smaller and has assisted in cutting down the weight of the pistons and other reciprocating parts.

The 1912 500-mile winner at Indianapolis had four cylinders with a bore of 5 in., whereas the modern speed creations have eight cylinders with a bore of little more than 2 in.

The ignition for a time was the limiting factor in engine speed, but this has been developed to such an extent that it is now keeping pace with the other developments. An eight-cylinder engine turning over 8000 r.p.m. would have to have 32,000 sparks per minute, or if two spark plugs per cylinder were used 64,000 sparks per minute, which is a great number for any magneto or battery system.

Before the advent of the supercharger for racing car engines, difficulty was experienced in getting proper carburetion, and some eight-cylinder engines had as many as eight carburetors on them, one for each cylinder.

The use of the supercharger changed this, for not only does it compress the charge and mix it, but distributes it so well to the different cylinders that now one, or at most two, carburetors are used.



Joe Dawson winning 500-mile race at Indianapolis in 1912. The car, a National, had four cylinders and a bore and stroke of 5 by 6¼ in., giving a piston displacement of 490.8. As shown by the chart above, the average speed of the engine was about 2200 r.p.m. as compared with the almost 8000 r.p.m. of the 91½ cu. in. Miller engine (see opposite page) which was used in the winning car this year

One of the difficulties encountered with supercharging is the heating of the mixture, due to its being compressed, and means have to be provided for cooling the mixture between the supercharger and the cylinder. Since the pressure developed in a cylinder due to combustion increases with the difference in temperature between the incoming and exploding gas, the cooler the gas can be supplied to the cylinder, the greater the power within the limits of good ignition.

Comparison showing great difference in size of valves and valve springs used in 1912 and 1927 cars at Indianapolis race

Intercoolers consisting of long tubes were at first used for this cooling of the charge. Lockhart's speed car had a large aluminum intercooler with fins on the outside flush with the top of the bonnet, and now most of the coolers are made in some such manner.

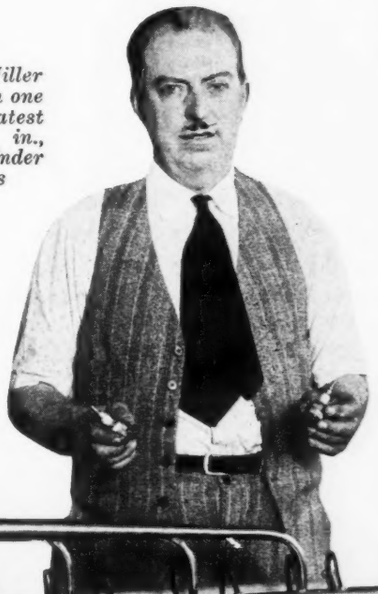
The mean effective pressure of these engines is quite high and the weight in pounds per horsepower compares very favorably with some of the recent airplane engines.

The limiting factors in the speed of an engine are the inertia forces set up and the strength and weight of materials used, assuming that the cylinders can be filled with gas by supercharging.

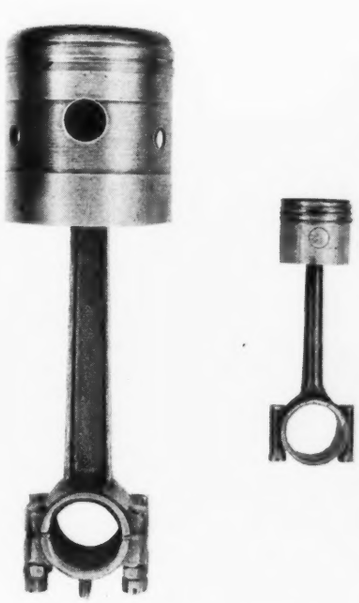
The centrifugal and reciprocating forces are the ones that worry us, as the explosive force is of very little moment at these high speeds. These forces at a given speed depend upon the mass of material moving, and the mass necessary depends upon the strength and weight of that material.

So to answer our question we might ask, Is it possible to use smaller parts and more of them, that is, a larger number of cylinders and smaller bore, or can we develop lighter and stronger steel and aluminum alloys, out of which to make pistons, rods, valves, valve springs and such parts.

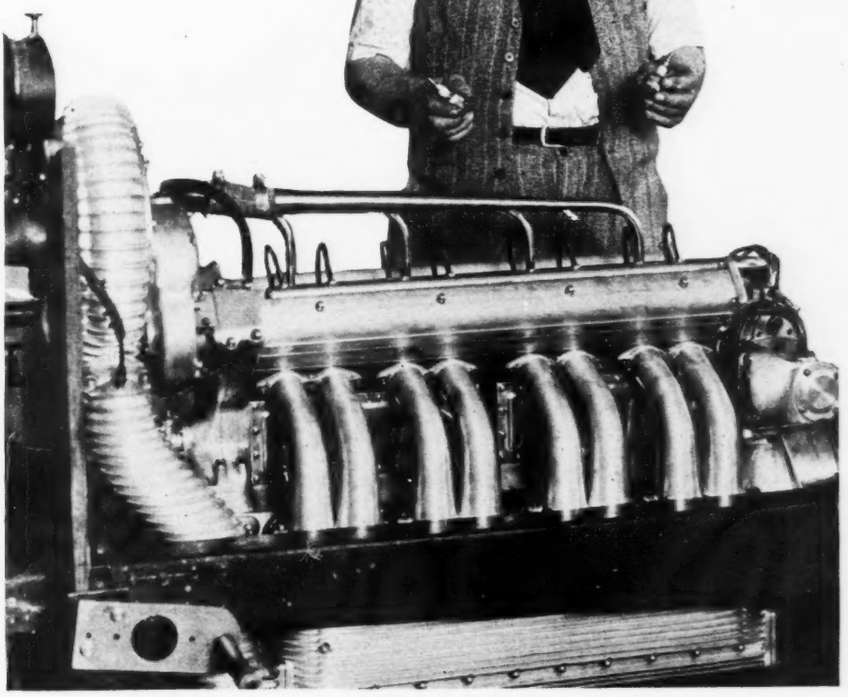
All of this looks feasible, but only the future can tell us definitely regarding how far it will be carried.



Harry Miller at work on one of his latest 91½ cu. in., eight-cylinder engines



Comparison of connecting rods and pistons of 1912 and 1927 racing cars



Airplane Engine Designers

Engineering development work is spread over many types. Air-cooled "Vee" and in-line engines attracting attention. Serious effort made to lower production costs.

By A. F. Denham

This split master connecting rod is used on the present series Wright J-5 engine, together with a solid crankshaft

ENGINEERING developments in airplane powerplants are so diverse in nature and involve so many different principles of design, operation and installation, that to draw any general conclusions is out of the question. Each type of powerplant has to be separately considered, both as regards its possibilities for future development and the general trend of design characteristics.

In the first place, there is still the argument between proponents of water-cooled and air-cooled engines. Then, in the air-cooled types, there are the now popular radial engines and the experimental V-type engines which are developments of water-cooled prototypes. In addition there are variations of both types, including the double-bank radial, the in-line type, the four-cylinder cam type, etc.

Air-Cooled Most Popular

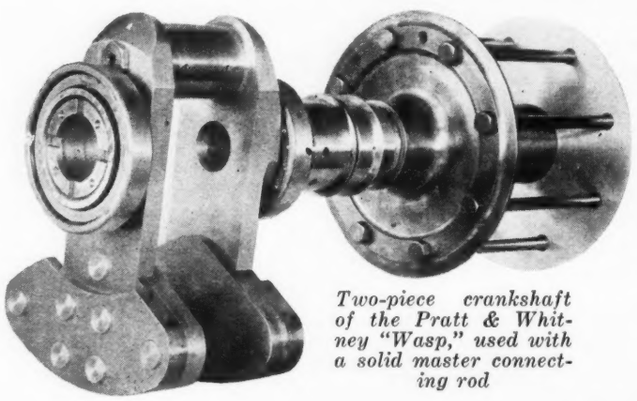
At present the radial air-cooled engine is the most popular type for commercial purposes. It is being built in sizes ranging from 40 to 525 hp. Among the leading builders of such engines in this country are the Wright Aeronautical Corp. (which first popularized this engine with the "Whirlwind" designed by Charles L. Lawrance); the Pratt & Whitney Aircraft Corp. with its "Wasp" and "Hornet"; the Warner Aircraft Corp.; the National Aeronautical Corp. producing the Cameron engines; the LeBlond Tool Co., which took over the Detroit Aircraft Engine Co.; the Velie Motor Car Co.; F. L. Odenbreit, Inc., and Pitcairn Aviation. There are other experimental engines including a sleeve valve type under development by Continental Motors Corp. Most of these engines have been described previously in *Automotive Industries*.

In addition there are a number of smaller engines, such as the Szekely 30 hp. three-cylinder, which will not be discussed here, however, since they can hardly be considered for "commercial" operation.

Foreign radial engines are also beginning to play a part in the field of smaller domestic commercial airplanes, with the importation of Siemens-Halske engines by the Ryan Aeronautical Corp. and of Anzani engines by the Brownback Motor Laboratories. The latter range from 30 to 120 hp. in size while the former range from 70 to 125 hp.

Most of the domestic companies mentioned offer at least two or three sizes of radial engines. The different engines usually have cylinders of the same size, the number of cylinders varying, with three as the minimum and nine as the maximum. This provides for interchangeability of assemblies on the various sizes of engine, including such parts as cylinders and liners, valve gears and pushrods, pistons and rings, etc. In a number of cases crankshafts are also made interchangeable between several sizes, with a view to cutting production costs, but at the expense of some extra weight in the smaller engine sizes. Accessories such as oil pumps, tachometer drives, fuel pumps, etc., can also generally be made interchangeable between different sizes of engine of the same general construction, and this procedure seems to be in general favor.

One of the most interesting variations in the general class of radial engines is found in the crankshaft, there being a fairly equal division between those favoring a split crankshaft and those adhering to the solid type. With the latter, of course, a split master rod is needed, while with the former a solid rod can be used. The arguments in favor of the solid connecting rod are that in the usual type of split rod, with a stepped split, cracks sometimes develop between the steps and the adjacent bolt hole, while, owing to the necessarily wide spacing of the clamping bolts,



Two-piece crankshaft of the Pratt & Whitney "Wasp," used with a solid master connecting rod

Following Diverse Lines

ONE of the most promising developments now in progress in the aeronautic field is the application of air-cooling to V-type and in-line engines. In general, the method of procedure is to take present types of water-cooled engines and remodel them by the elimination of water jackets and the substitution of cooling fins.

Two of the chief problems involved are to obtain adequate cooling for the rear cylinders and the location of accessories in such a manner as not to interfere with the cooling system.

Nearly all experimental air-cooled V-type engines are of the inverted type, this form lending itself better to the installation of the necessary air ducts and their fairing into the fuselages.

heavy bending stresses are set up in the bolts themselves, resulting sometimes in splitting of the bolt bosses.

In adopting the solid rod, the design problem is shifted to the crankshaft. With the one-piece shaft and split rod, a more rigid crankshaft can be built, and considerations of ease of assembly place fewer restrictions on the layout of the engine. The solid type of crankshaft makes possible the use of a single-piece crankcase, while the split type requires splitting of the crankcase through the center, to permit of assembly. The most popular design of a two-piece crankshaft involves the use of telescoping crankpins which may be of the tapered or stepped type, assembly being effected either by a nut on the inner telescoping half, or by a bolt passing through the center of the hollow crankpin, a nut drawing the halves together. The former method is employed by Siemens-Halske, the latter by Pratt & Whitney. Another variation of this construction is used by Velie. In this case the crankpin is solid and is keyed to the rear crankarm, which is split at the top. A bolt through the halves of the arm locks the crankpin and key in place.

Anti-Friction Bearings

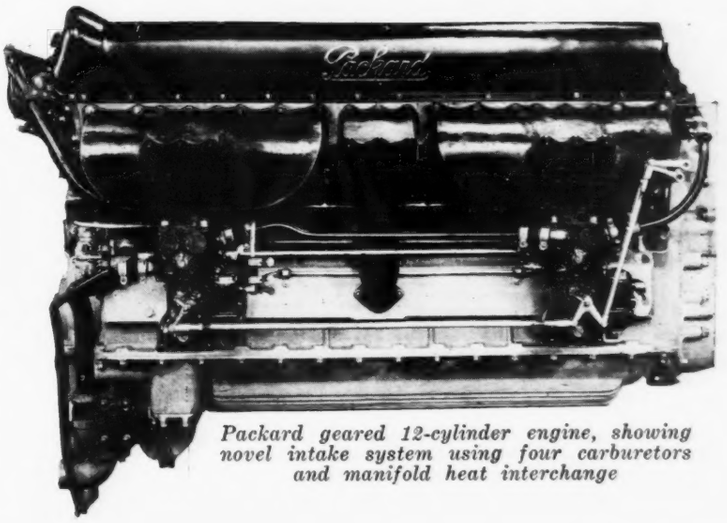
There has been a general tendency toward the use of anti-friction bearings in radial engines, and some designers have taken advantage of the split type of shaft to use ball or roller bearings for the master rod on the crankpin, although this is not general. This tendency to anti-friction bearings is due to the fact that they simplify the lubrication problem, besides which maximum operating efficiency through reduction of friction losses is considered more important than low cost.

There are also numerous design variations in the master rod itself, but the general principle is always the same. In domestic engines, articulated rods are generally provided with a bronze bushing through which passes a pin pressed into lugs in the master rod. Since with the radial type of engine there are considerable stresses on these articulated rods as well as on the master rods, and since the general construction does not often allow the use of large masses, light metal alloys have not yet come into general use for rod construction. On the other hand, all pistons are of light alloys and relatively short in comparison with the bore. They are generally also of fairly conventional design, with solid skirts and ribbed heads.

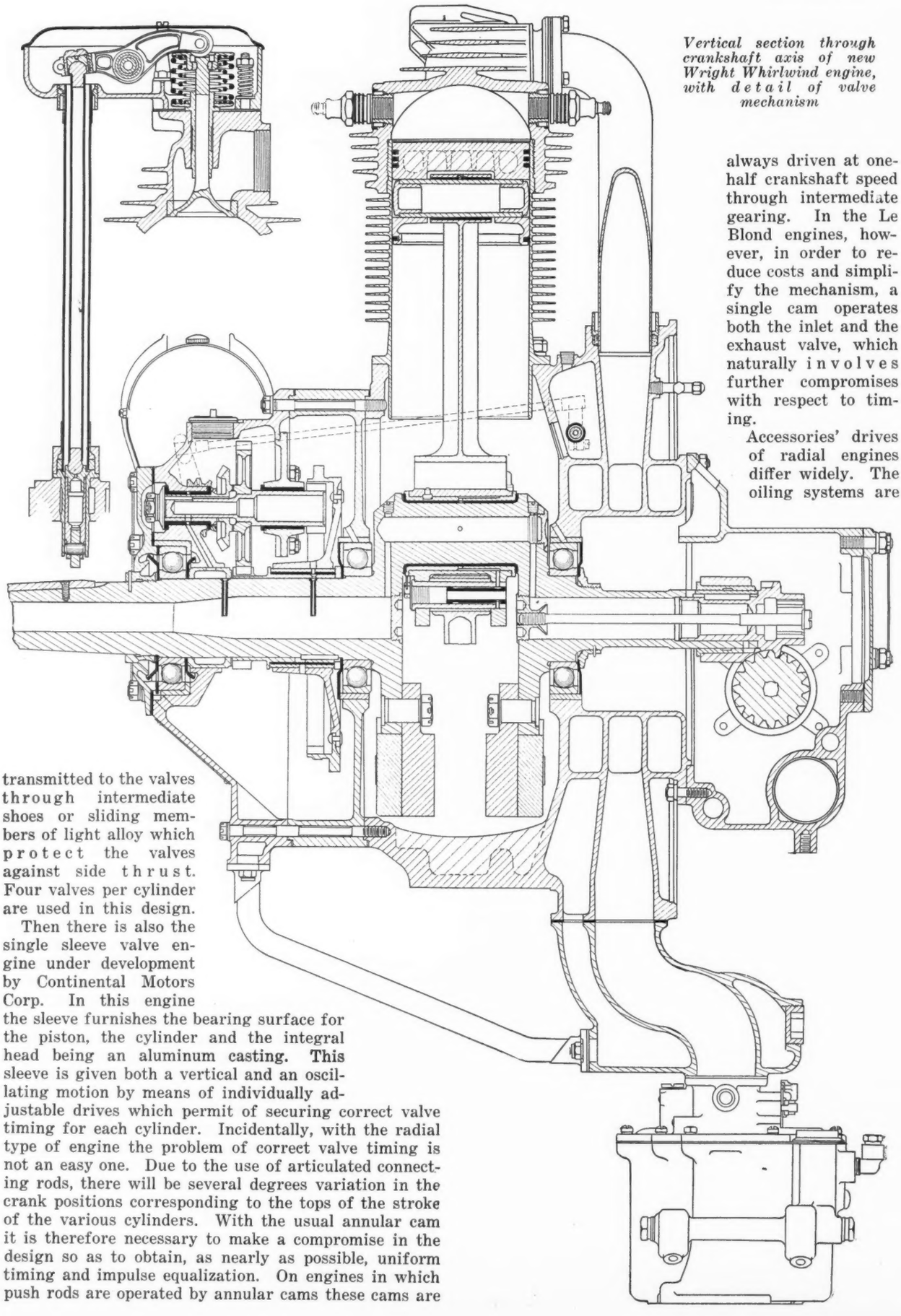
Three general types of cylinder construction are made use of. The first, which comprises a steel sleeve screwed into a full length aluminum cylinder with integral head, has lost somewhat in popularity, on account of weight and expansion considerations, its place having been taken by a composite structure. In the latter the steel sleeve, which is generally bolted to the crankcase, forms the lower part of the cylinder and has integrally machined cooling fins. The upper part of the cylinder is integral with the head and is of an aluminum alloy casting with integral fins. It is generally screwed and shrunk to the steel sleeve. In the third form of construction the head alone is of aluminum and bolted to the steel cylinder proper. This form of construction is quite popular for the smaller, lower priced engines, cast iron being substituted for steel.

Valve Operating Mechanisms

Considerable experimental work is being carried on at present on valve operating mechanisms. Most radial engines have two valves per cylinder and use the push rod and rocker arm system, the valves being actuated by a rotating annular cam in the crankcase. Complete inclosure of this valve gear, to keep out dust and retain the lubricant, is a feature of modern practice. Of the more radical departures there is one incorporated in the Cameron engine which substitutes for the up-and-down motion of the push rod an oscillating motion



Packard geared 12-cylinder engine, showing novel intake system using four carburetors and manifold heat interchange



Vertical section through crankshaft axis of new Wright Whirlwind engine, with detail of valve mechanism

always driven at one-half crankshaft speed through intermediate gearing. In the Le Blond engines, however, in order to reduce costs and simplify the mechanism, a single cam operates both the inlet and the exhaust valve, which naturally involves further compromises with respect to timing.

Accessories' drives of radial engines differ widely. The oiling systems are

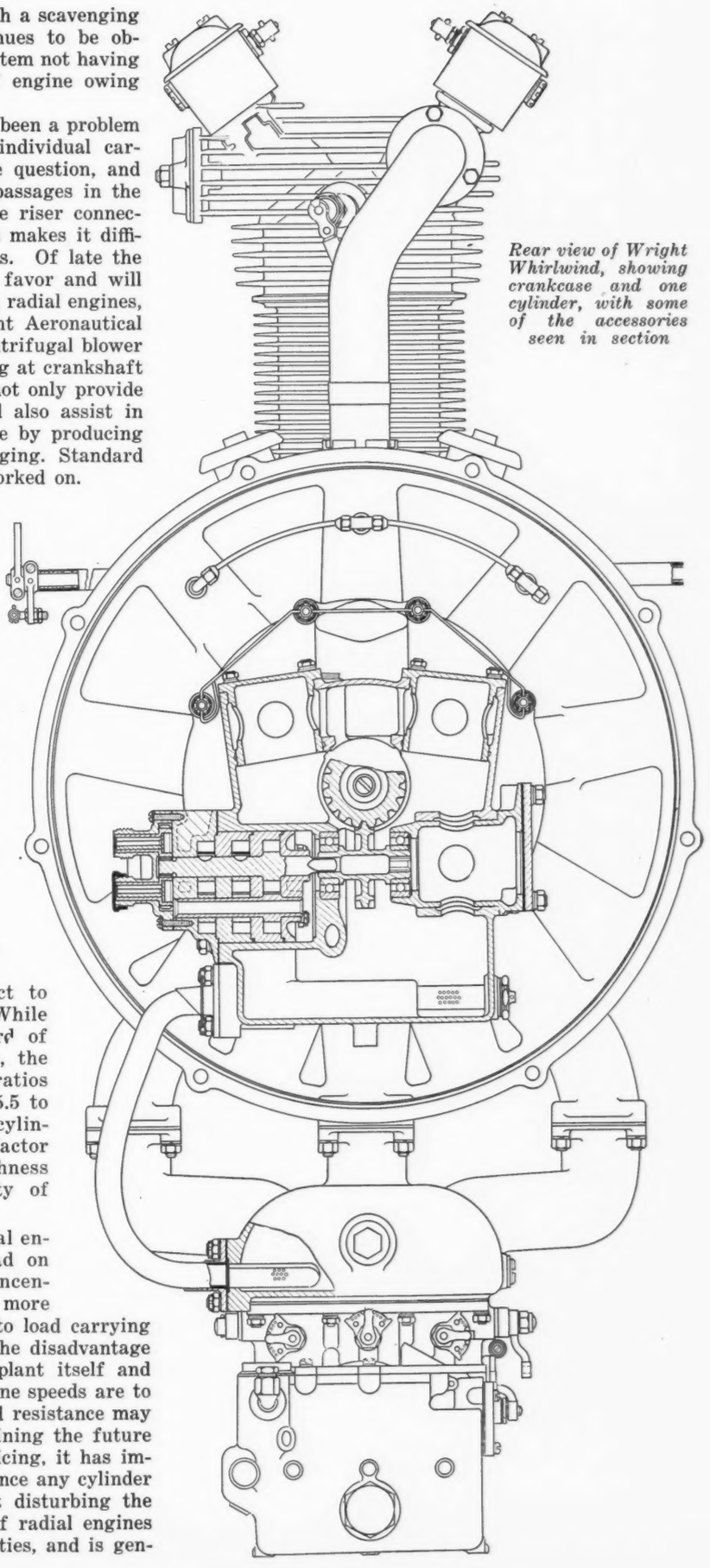
transmitted to the valves through intermediate shoes or sliding members of light alloy which protect the valves against side thrust. Four valves per cylinder are used in this design.

Then there is also the single sleeve valve engine under development by Continental Motors Corp. In this engine the sleeve furnishes the bearing surface for the piston, the cylinder and the integral head being an aluminum casting. This sleeve is given both a vertical and an oscillating motion by means of individually adjustable drives which permit of securing correct valve timing for each cylinder. Incidentally, with the radial type of engine the problem of correct valve timing is not an easy one. Due to the use of articulated connecting rods, there will be several degrees variation in the crank positions corresponding to the tops of the stroke of the various cylinders. With the usual annular cam it is therefore necessary to make a compromise in the design so as to obtain, as nearly as possible, uniform timing and impulse equalization. On engines in which push rods are operated by annular cams these cams are

all of the dry sump type, comprising both a scavenging and a pressure pump. Ignition continues to be obtained through magnetos, the battery system not having made much progress with this type of engine owing to the weight considerations.

The method of fuel supply always has been a problem with radial engines. The use of an individual carburetor for each cylinder is out of the question, and a single carburetor necessitates cored passages in the crankcase to conduct the mixture to the riser connections for the individual cylinders. This makes it difficult to obtain good idling characteristics. Of late the rotary induction system has come into favor and will shortly be standard equipment on several radial engines, including the new models of the Wright Aeronautical Corp. This system is composed of a centrifugal blower mounted on the crankshaft and operating at crankshaft speed within the crankcase. It should not only provide better idling characteristics but should also assist in increasing the horsepower of the engine by producing what amounts to low pressure supercharging. Standard types of supercharger are also being worked on.

One of the problems which is coming to the fore in commercial engine design is that of proper muffling. With the radial engine this necessitates the use of a collector ring which must be so designed that it will not interfere with the cowling of the engine. An individual exhaust stack for each cylinder is another solution, and one type, consisting of a conical stack with a slit from end to end, is now in fairly wide use. This system, however, does not permit of using exhaust gases for heating purposes—an important factor in cabin type airplanes. Exhaust gases are not used for heating the inlet as carburetors are generally oil-jacketed.



Rear view of Wright Whirlwind, showing crankcase and one cylinder, with some of the accessories seen in section

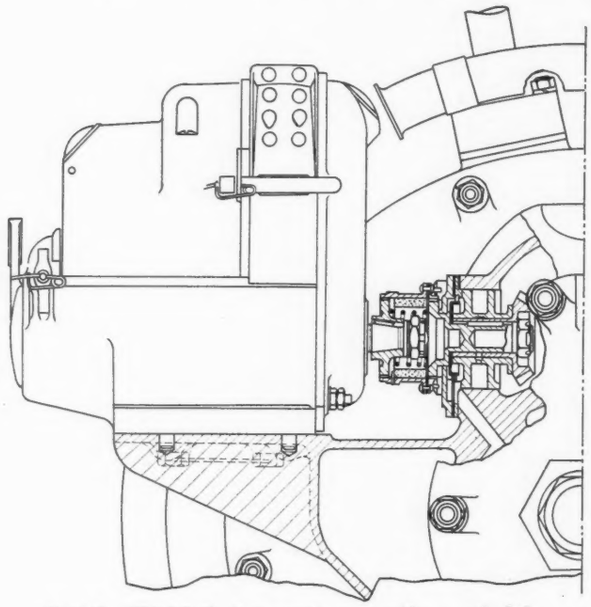
Lower Compression

In general the radial engine is subject to the same limitations as other air-cooled engines with respect to power available per cubic inch. While brake mean effective pressures upward of 135 lb. p. sq. in. are not uncommon, the tendency is to reduce compression ratios rather than to increase them, 5.3 to 5.5 to 1 being the upper limit. Valve and cylinder head cooling is a determining factor along with detonation control, smoothness of operation and decrease in quality of available commercial fuels.

Compared with other types, the radial engine has the advantage that the load on supporting members is more nearly concentrated in one plane, which permits of more effective fuselage design with respect to load carrying capacity. This, however, is offset by the disadvantage of greater frontal area of the powerplant itself and increased cowling difficulties. If airplane speeds are to be increased materially this added head resistance may become an important factor in determining the future of the radial engine. As regards servicing, it has important advantages over other types, since any cylinder can be removed and replaced without disturbing the rest of the engine. The installation of radial engines also does not present any great difficulties, and is gen-

erally very simply effected through the use of quick detachable engine mounts. The radial type also lends itself well to quantity production, because many of its parts are used in multiple units.

There are very strong evidences that considerable attention is now being given to reducing manufacturing costs, in spite of the fact that the demand exceeds the supply. The major changes in the new series Wright "Whirlwind" are of such a nature as to reduce manufacturing costs. For example, the link rods have been changed from a tubular to an I-beam section in order to eliminate the boring and reaming operations required on the former type. For the pistons a single core is used, instead of the three formerly required, the piston having been slightly redesigned to make this possible.



Wright Whirlwind magneto mounting and drive

Opinions vary as to the best methods of reducing costs, and there are those who believe that cost reduction at the expense of some increase in weight is warranted.

An extremely interesting development is the new Curtiss Hexagon, described in the May 19 issue of *Automotive Industries*. It is not strictly a radial engine, but is composed of two banks of six cylinders each, raidally disposed about a central crankcase, with each cylinder of the rear bank immediately back of a front cylinder. The crankshaft is of the double-throw type and each pair of cylinders is provided with an overhead camshaft, gear-driven from the crankshaft through intermediate gearing. With this construction the overall diameter is considerably decreased, while the necessity of adjusting push rods for expansion is eliminated through the use of the overhead camshaft, which also enables the use of four valves per cylinder.

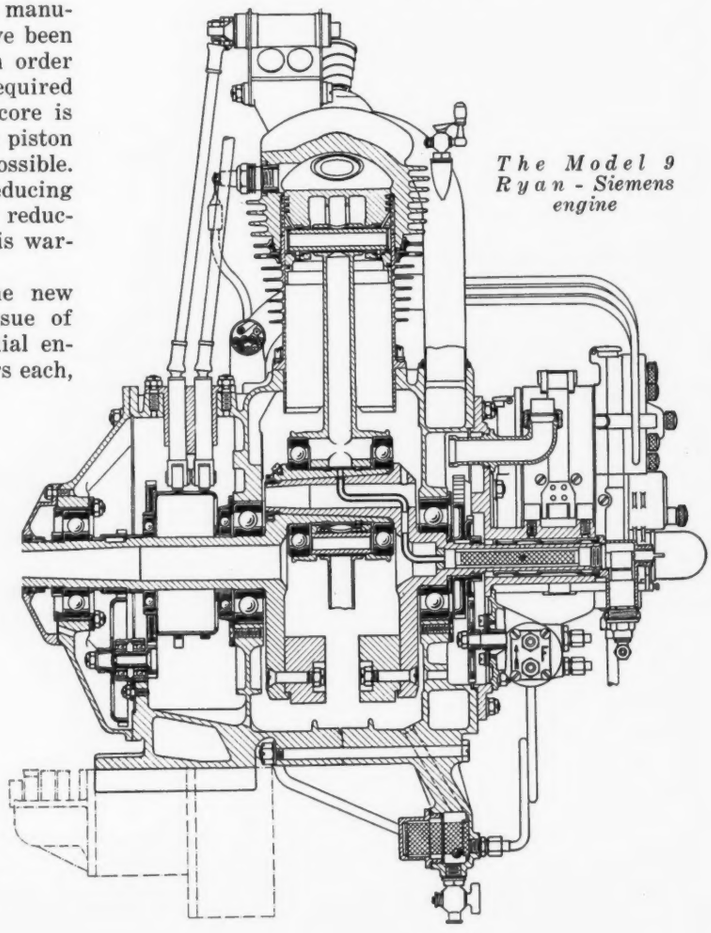
Another deviation from conventional radial engine practice is found in the Fairchild "Cam" engine, a two-lobed cam being substituted for the usual crankshaft, which results in halving the propeller speed. This engine also has been previously described in *Automotive Industries*, and its details are now rather well known. The object of this type of construction is to combine high specific output of the engine with the propeller efficiency, which latter involves low rotational speeds.

One of the promising developments now in progress is the application of air-cooling to V-type and in-line engines. In general the method of procedure is to take present types of water-cooled engines and remodel them by the elimination of water jackets and the substitution of cooling fins. Considerable experimental work along these lines has been carried on both at McCook Field and at the Allison Engineering Laboratories, using the Liberty engine as a basis. The Wright Aeronautical Corp. is also working on an air-cooled edition of its Tornado 600 hp. engine, but this is still in the experimental stage. Two of the chief problems involved are to obtain adequate cooling for the rear cylinders and the location of accessories in such a manner as not to interfere with the cooling system.

Nearly all experimental air-cooled V-type engines are of the inverted type, this form lending itself better to the installation of the necessary air ducts and their fairing into the fuselages. The same general problem arises in the design of in-line engines. In addition, it is difficult with this type of engine to keep the weight within desirable limits, as the crankcases must of necessity be large. Either individual cylinders or block castings can be used, but the former are generally preferred because they permit of a saving in weight and facilitate replacements of cylinders in service.

Turning now to the water-cooled types of engine, we find that these have made little progress in the commercial field since the practical exhaustion of war-time stocks. This is due chiefly to the fact that develop-

(Continued on page 985)

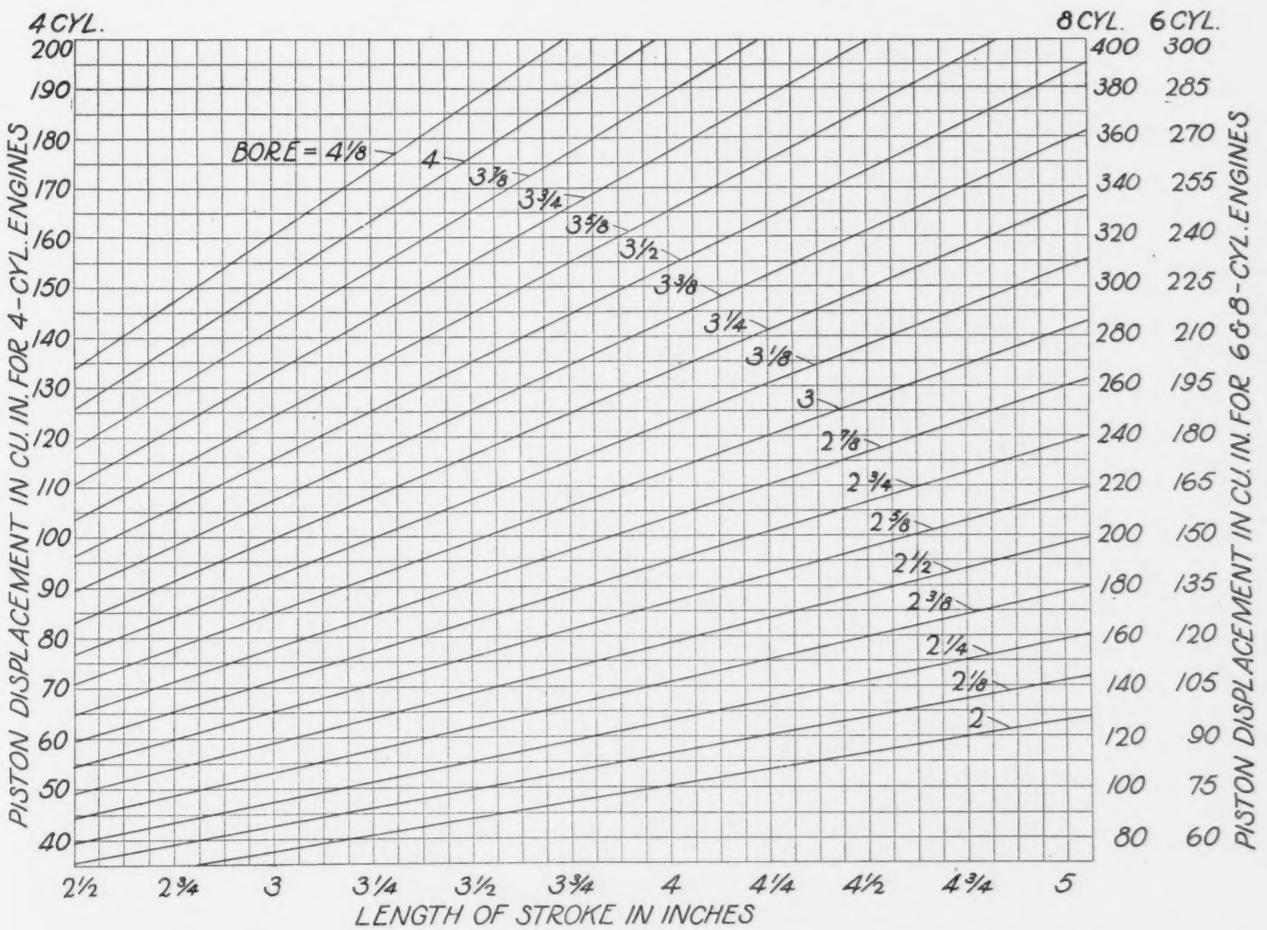


The Model 9 Ryan - Siemens engine

16 Practical Reference Engineering Charts

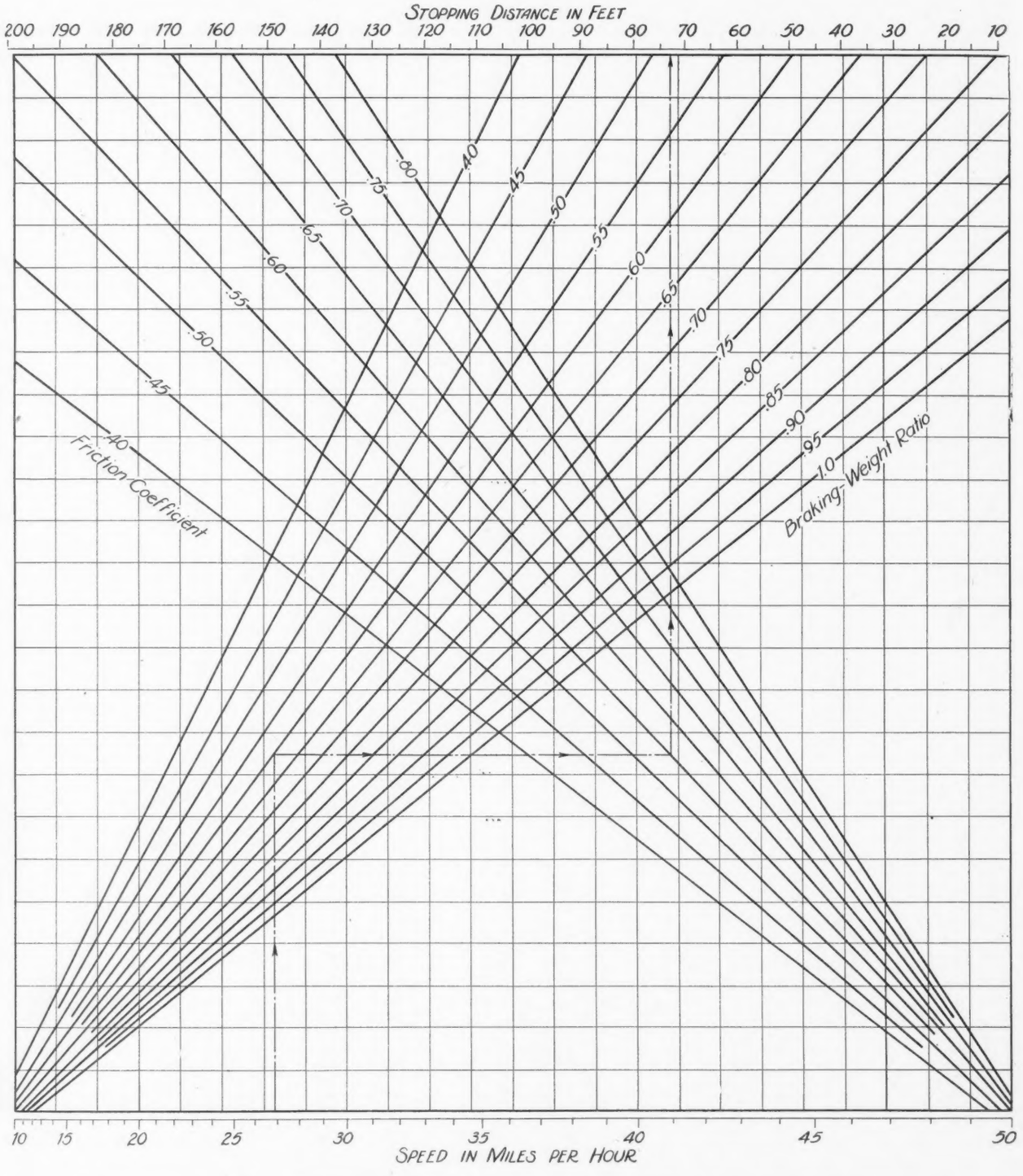
THE charts on this and the following pages are presented as offering to automotive engineers a quick and easy means of solving many of the everyday problems that arise in connection with their work. Some of the charts, such as those of piston displacement and engine speed in relation to car speed, represent absolute mathematical relations, while others, such as that for the capacity of dry multiple disk clutches, involve experience factors, the values of which are given in each case in the explanatory notes at the bottom of the page. While it is not possible to secure the same degree of accuracy from a chart of this kind as by carrying through the calculation, in most lines of engineering work it is unnecessary to insist upon a degree of accuracy closer than within 1 or 2 per cent, and this can always be attained with the charts. In the cases of all of the more complicated charts the method of use is indicated by an example. These charts are of what is known as the rectangular coordinate type.

Engine Piston Displacement, Small-Cylinder Range



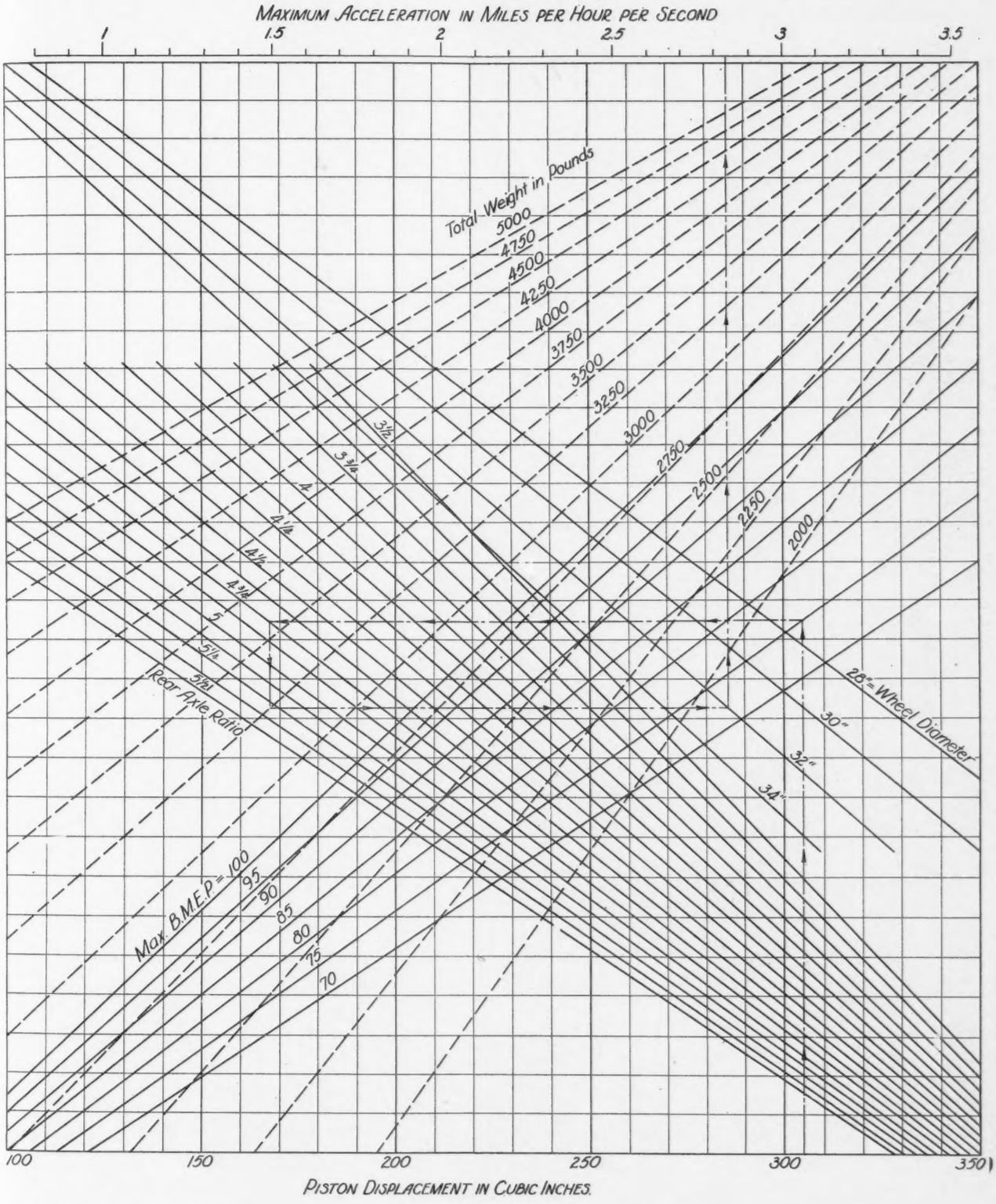
With the aid of the above chart the piston displacements of four, six, and eight-cylinder engines of cylinder dimensions usually met with in passenger car practice can be readily determined. Locate the stroke on the scale at the bottom, proceed upward to the inclined line representing the bore and thence horizontally to the right or left, where the displacement can be read off on the appropriate scale

Distances in Which Vehicles Can be Stopped by Brakes



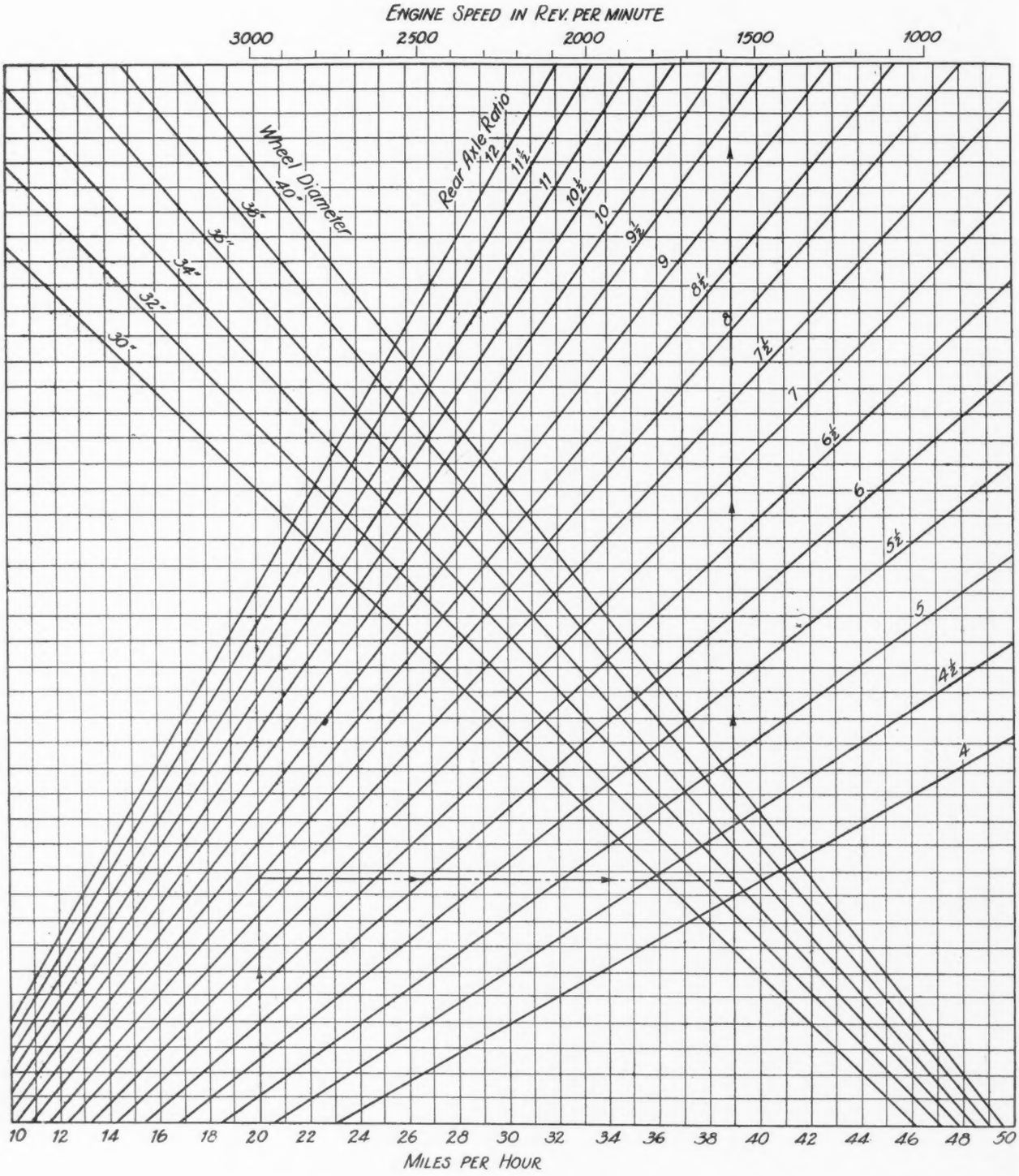
To determine the minimum stopping distance, locate the initial car speed on the bottom scale; proceed upward to the incline representing the ratio of the weight on the wheels on which the brakes act to the total moving weight (which is 1 for four-wheel brakes), thence horizontally to the incline representing the friction coefficient between tire and road and thence vertically to the scale at the top, which gives the desired result. The effects of air resistance and of inertia of rotating parts (which are opposed to each other and cancel out more or less) are neglected

High-Gear Car Acceleration



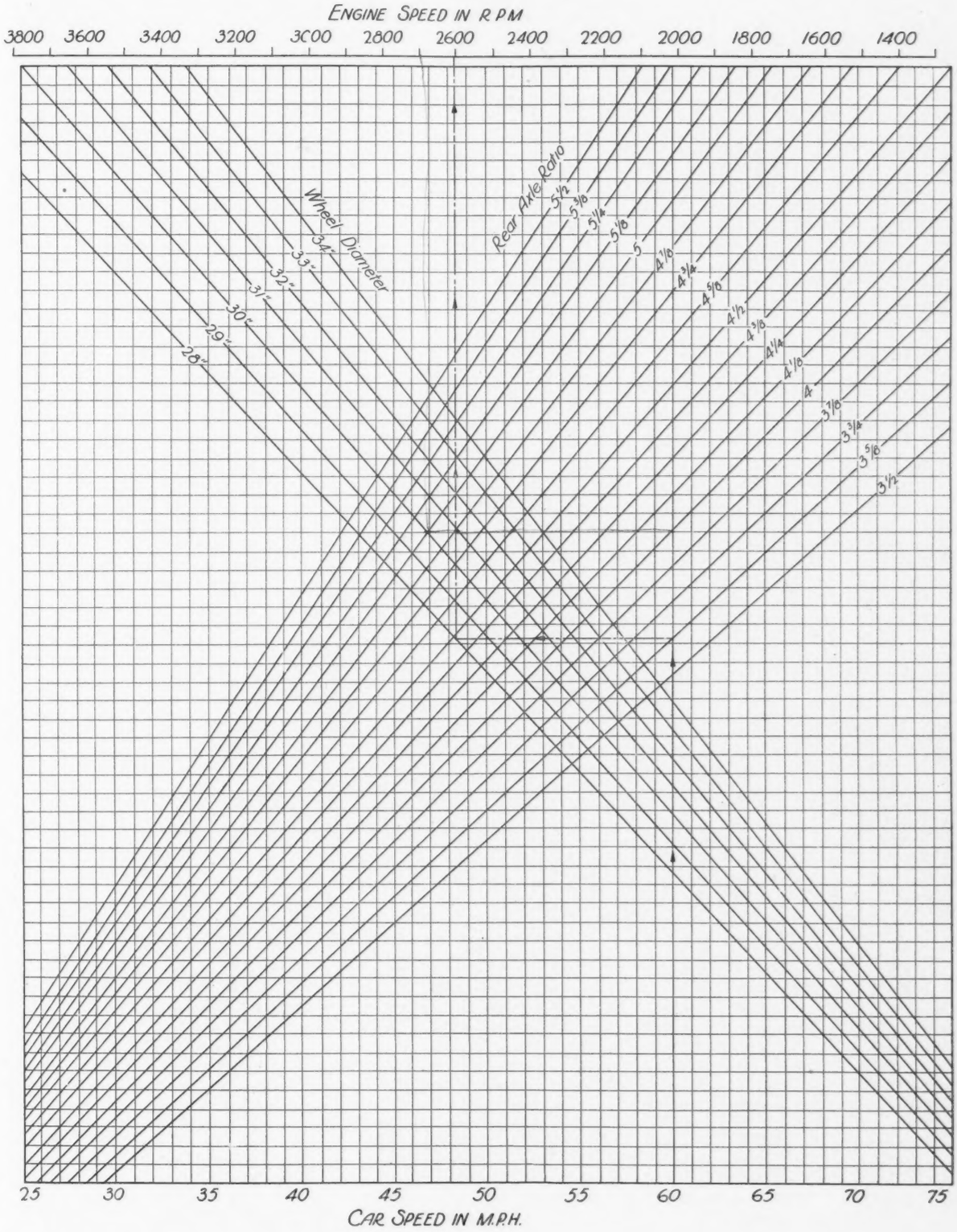
To determine the approximate maximum acceleration of a car in high gear proceed as follows: Locate the piston displacement on the bottom scale; proceed upward to the incline representing the maximum b.m.e.p., thence horizontally to the incline representing the rear axle ratio, thence vertically to the incline representing total car weight, thence horizontally to the incline representing wheel diameter and thence vertically to the scale at the top. The chart is based on the assumption of a rolling resistance of 20 lb. per 1000 and a mechanical efficiency of 90 per cent. The effects of air resistance and inertia of rotating parts are neglected

Engine Speed in Relation to Vehicle Speed, Truck Range



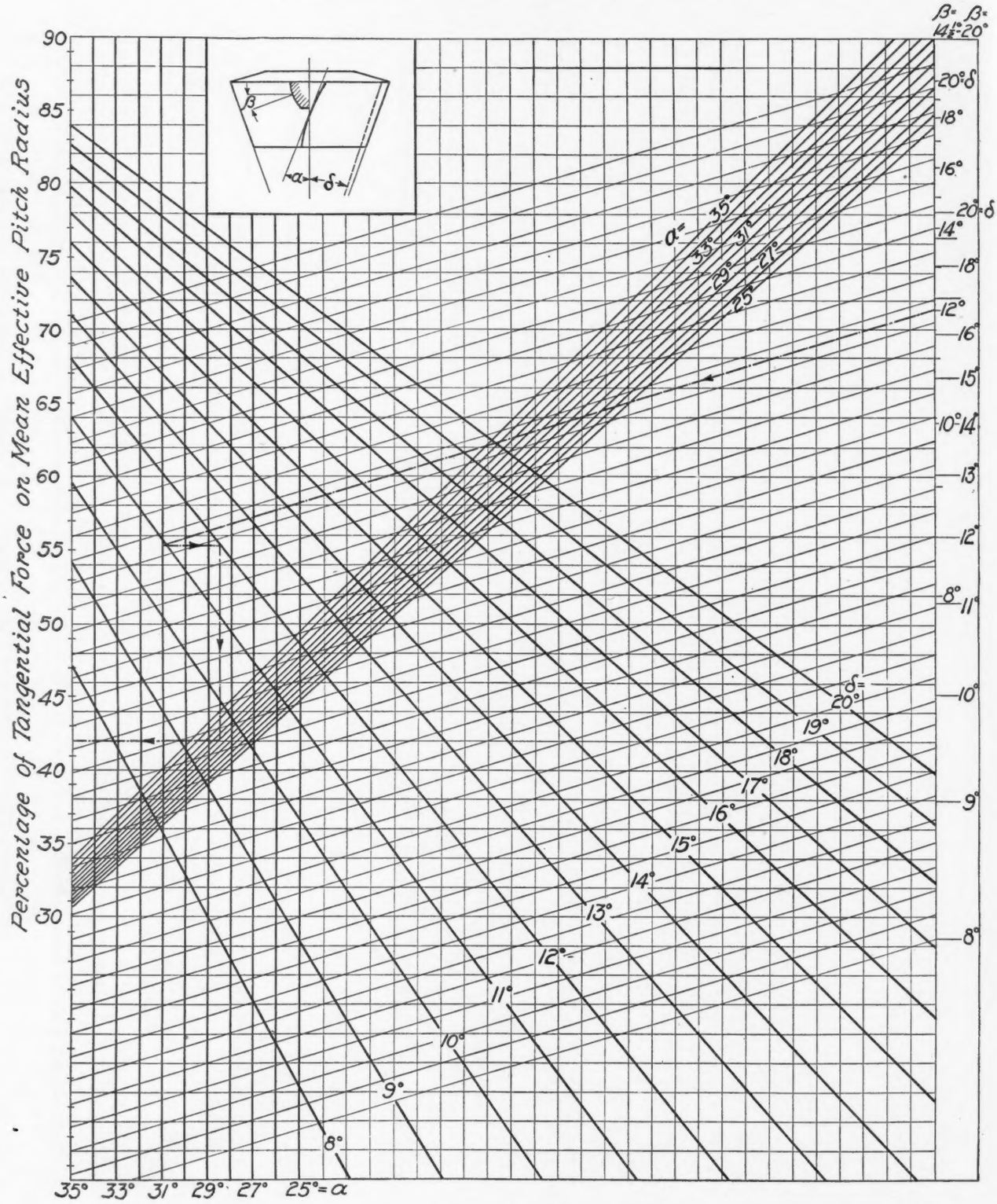
To determine the speed at which the engine is turning over when the truck is running at any particular road speed, locate this latter speed on the bottom scale, proceed upward to the inclined line representing the rear axle reduction ratio, thence horizontally to the right or left to the inclined line representing the wheel diameter, and thence vertically to the scale at the top, where the engine speed can be read off

Engine Speed in Relation to Car Speed, Passenger Car Range



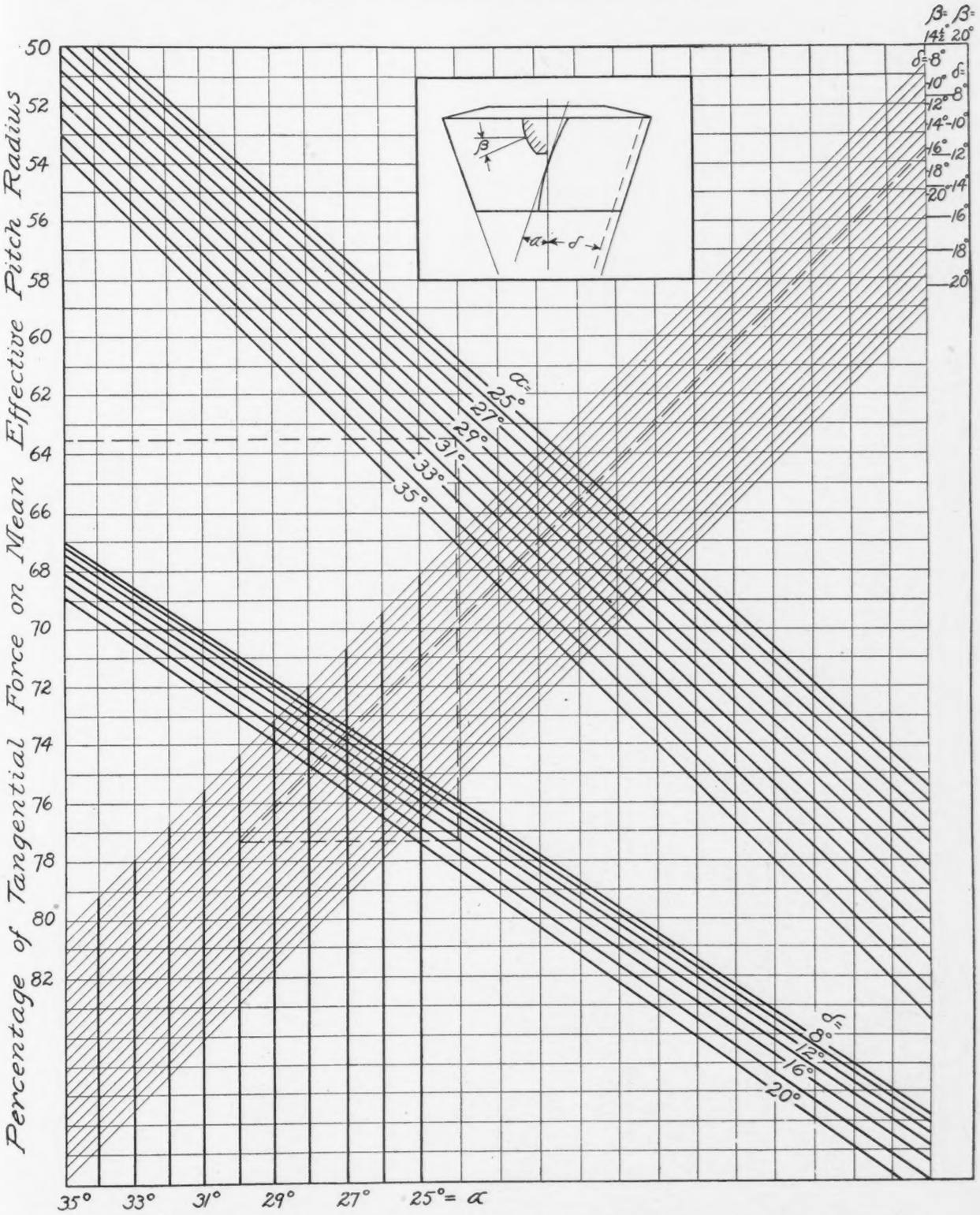
To determine the speed at which the engine turns over when the car is running at any particular speed, locate this latter speed on the bottom scale, proceed vertically upward to the inclined line representing the rear axle ratio, thence horizontally to the right or left to the inclined line representing the wheel diameter and thence vertically upward to the scale at the top, where the engine speed can be read off

Bearing Loads With Spiral Bevel Gears (Right-Hand Combination)



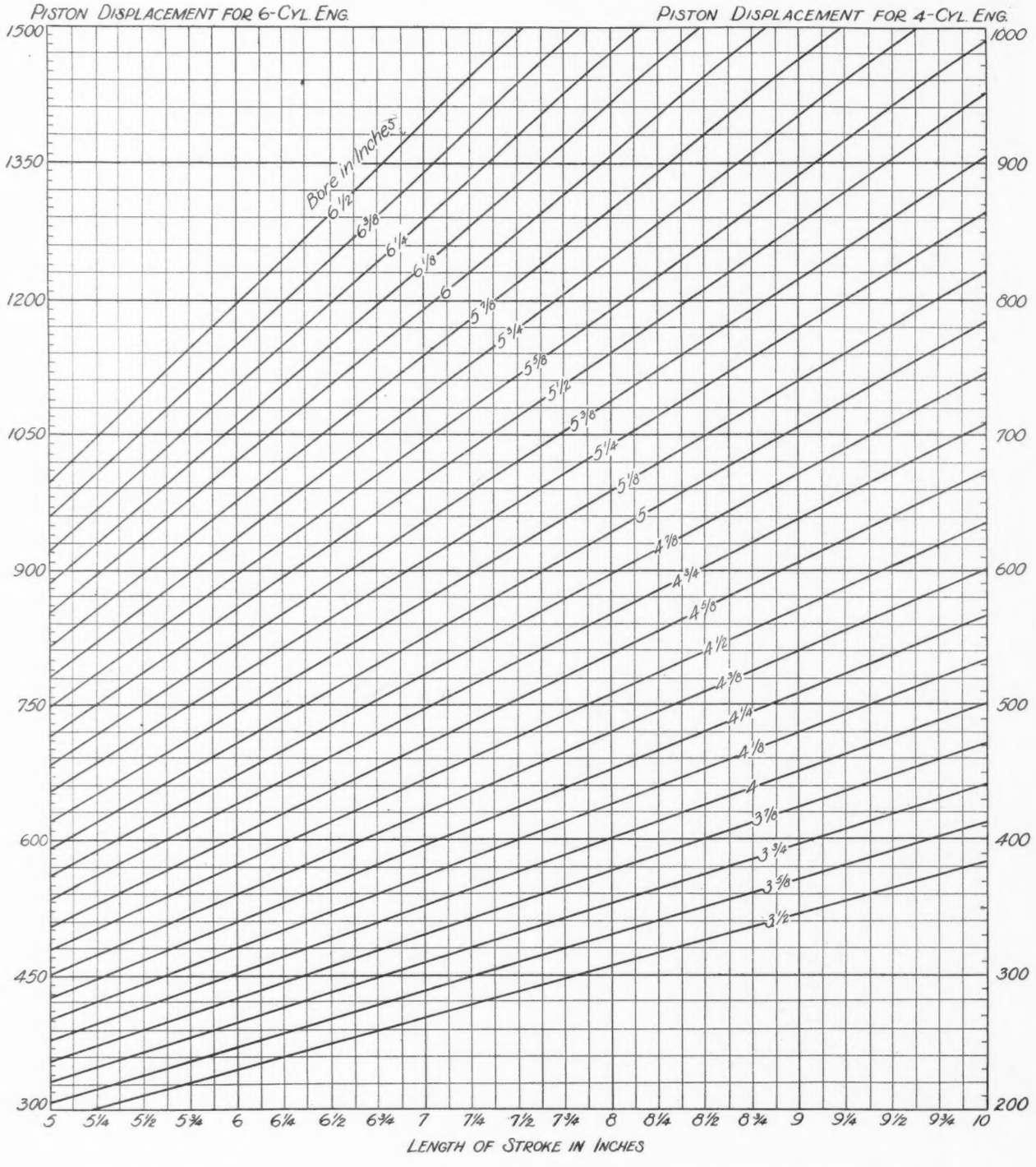
The above chart serves to determine the radial load on the pinion and the end thrust on the gear of a spiral bevel gear set comprising either a right-hand pinion turning right-handedly (forward motion) or a left-hand pinion turning left-handedly (reverse motion). The bearing load is given as a percentage of the tangential force on the mean effective pitch radius. Chart is used as indicated by the dotted lines

Bearing Loads With Spiral Bevel Gears (Left-Hand Combination)



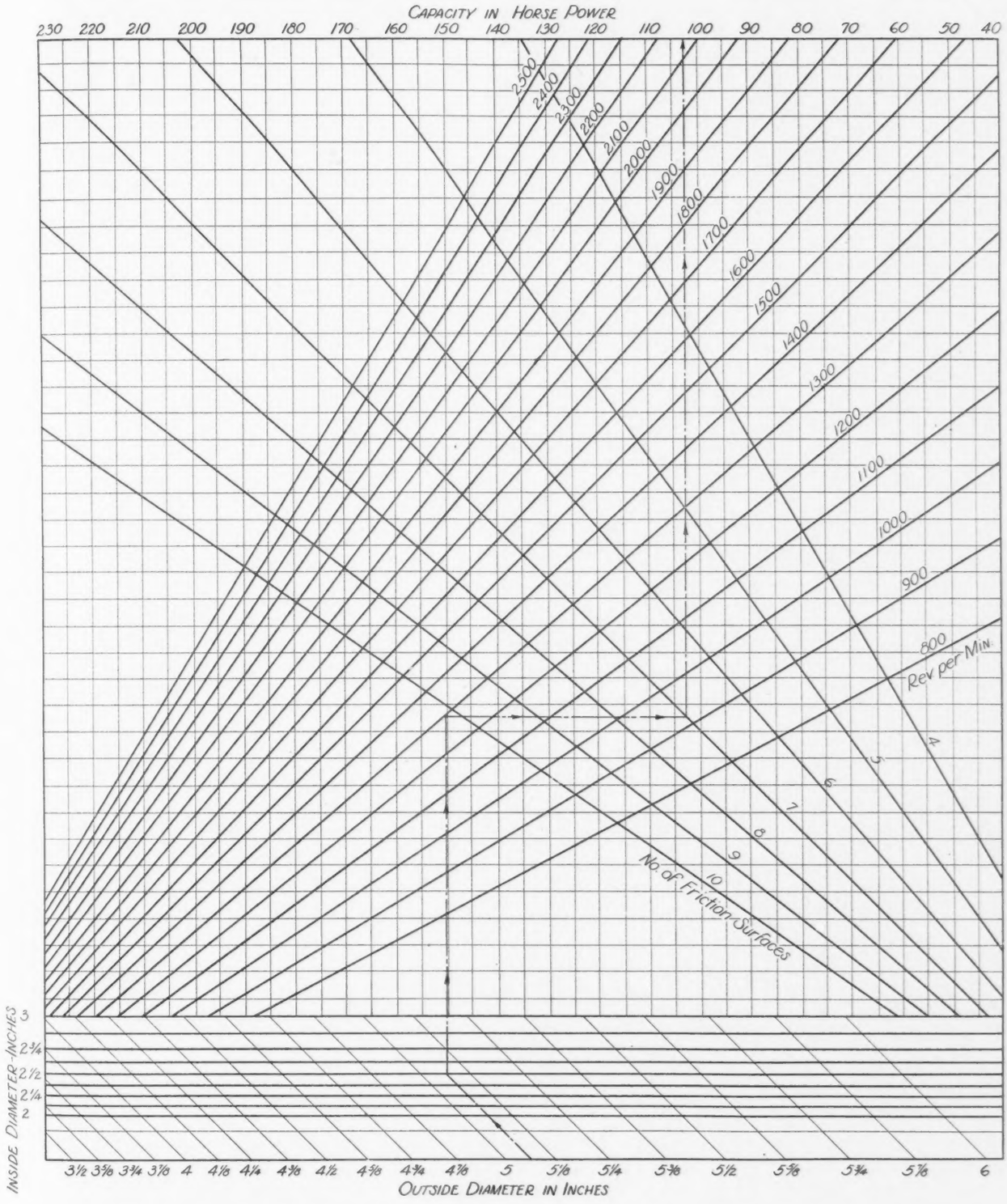
The above chart gives the thrust load on the pinion shaft and the radial load on the gear shaft (which are equal) of a spiral bevel set comprising a left-hand pinion turning right-handedly (forward motion) or a right-hand pinion turning left-handedly (reverse motion). Start at the upper right-hand corner, using the scale under the value of the pressure angle applying to the case in hand, and proceed as indicated by the dashed line. The bearing load as a percentage of the tooth load or tangential force on the pinion is read off on the scale at the left

Engine Piston Displacement, Large Cylinder Range



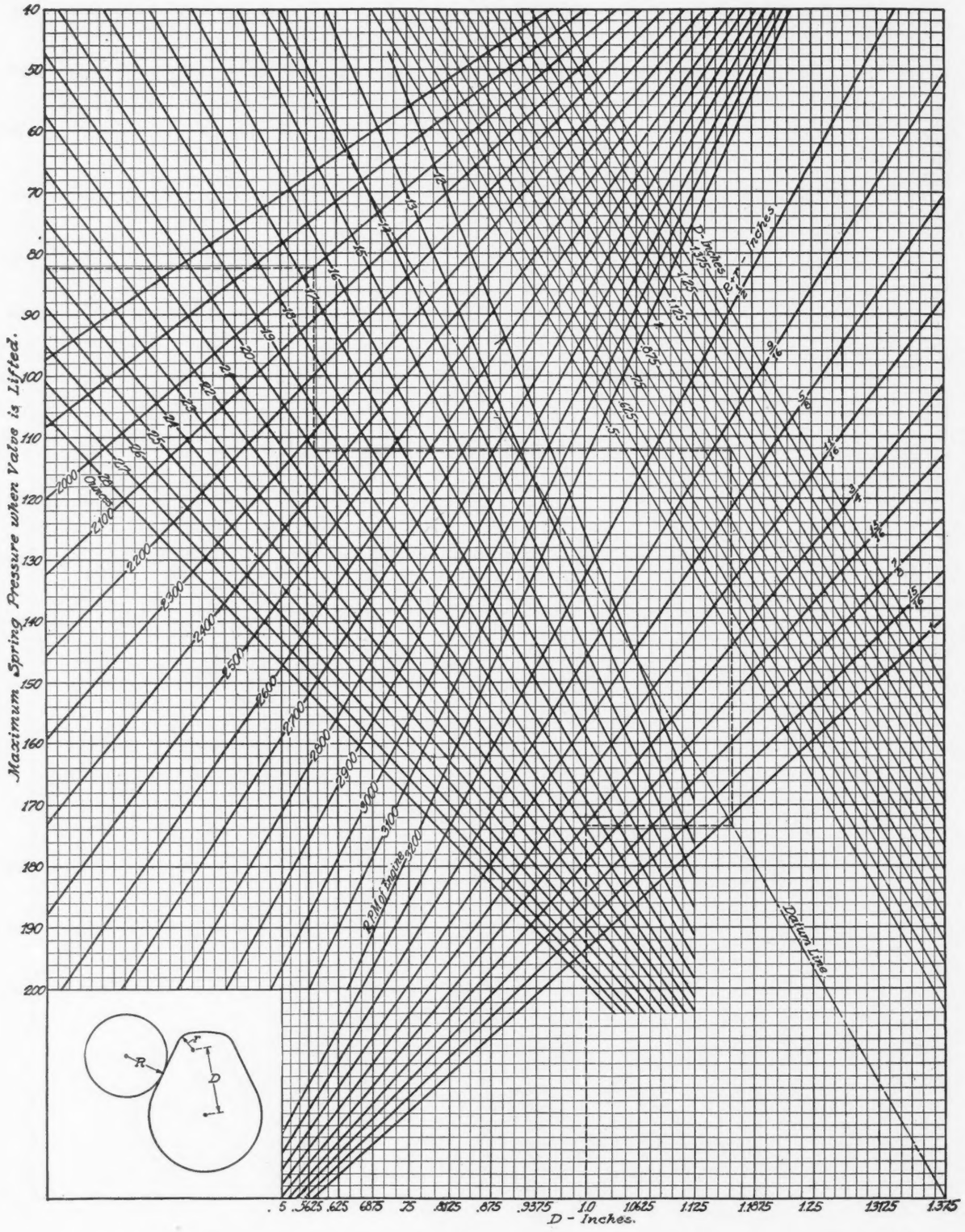
This chart serves to determine the piston displacements of larger engines as used on trucks and buses and in industrial work. Locate the stroke on the bottom scale, proceed vertically upward to the intersection with the incline representing the bore, and thence horizontally to the right or left, where the displacement can be read off on the vertical scale

Capacity of Multiple Dry Disk Clutches



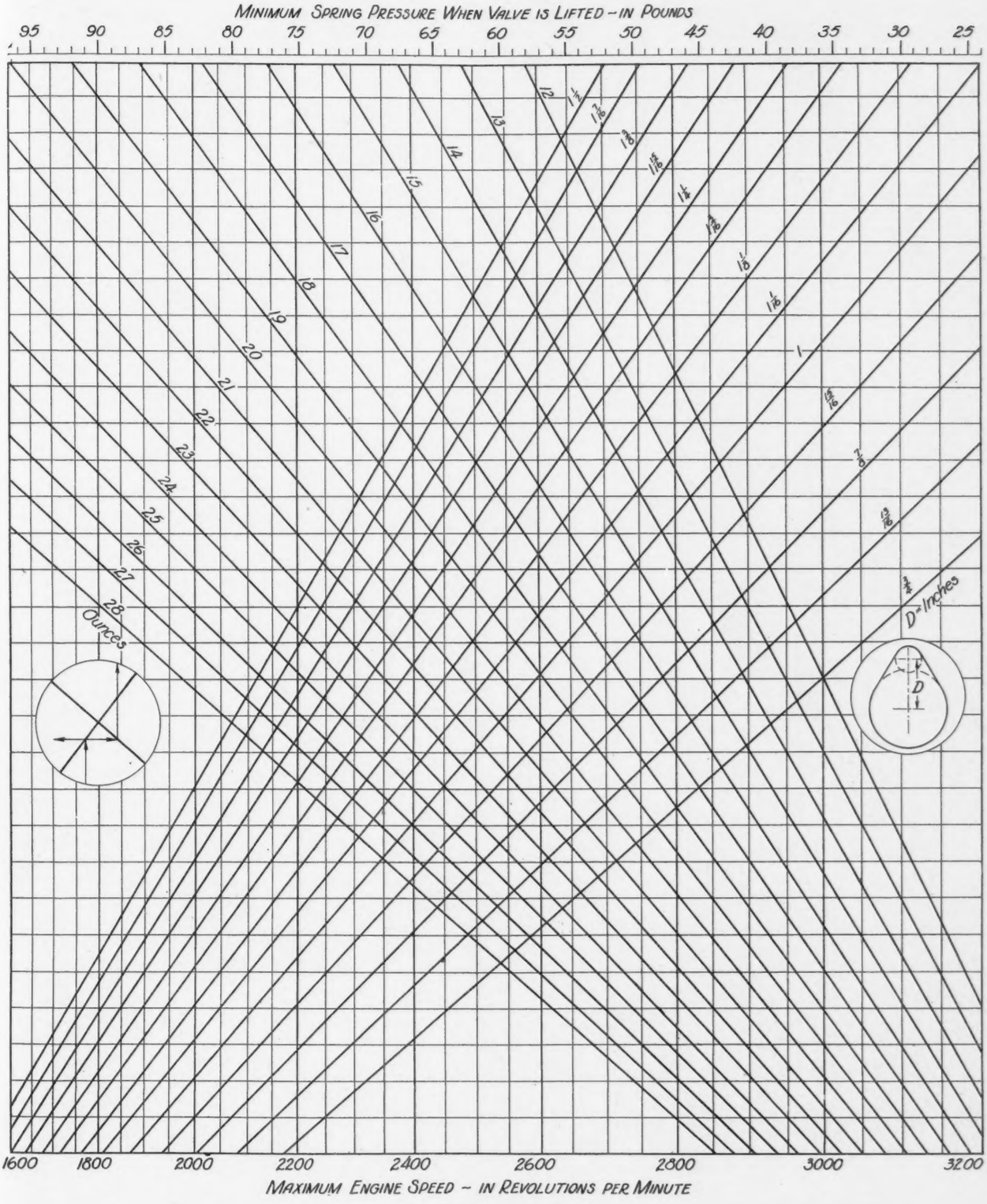
With the aid of the above chart the horsepower which can be safely transmitted by a multiple disk clutch can be determined in the following manner: Locate the outside diameter of the friction surface on the bottom scale; proceed parallel with the inclined lines to the horizontal line representing the inside diameter of the surface; thence vertically to the inclined line representing the speed of rotation, thence horizontally to the inclined line representing the number of friction surfaces and thence upward to the scale at the top, where the horsepower capacity is read off. This chart is based on a unit frictional force of 3 lb. p. sq. in.

Valve Spring Pressure Required With Tangential Cams



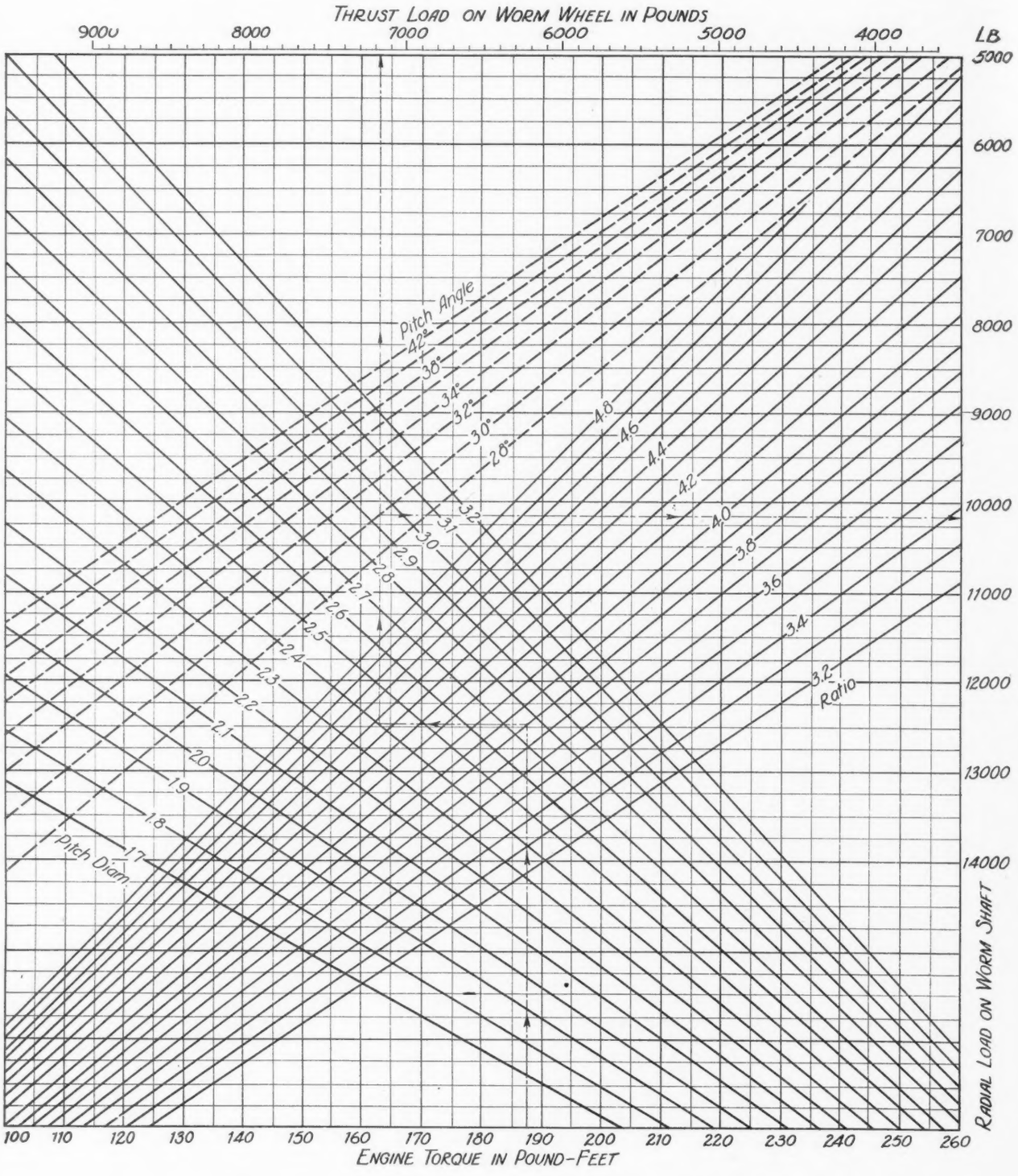
The chart gives the minimum pressure which the spring must exert when the valve is lifted. It is used as follows: Start from that point on the bottom scale denoting the distance D between the centers of the base circle and the rounding circle of the cam, proceed upward to the inclined line representing the value R + r (see sketch), then to the right to the Datum Line, then upward to one of the parallels representing the distance D, then to the left to one of the inclined lines representing the weight of the valve reciprocating parts, then up or down to one of the inclined lines representing the maximum engine speed, and then to the left to the scale giving the spring pressure required

Valve Spring Pressure Required With Mushroom Follower Cams



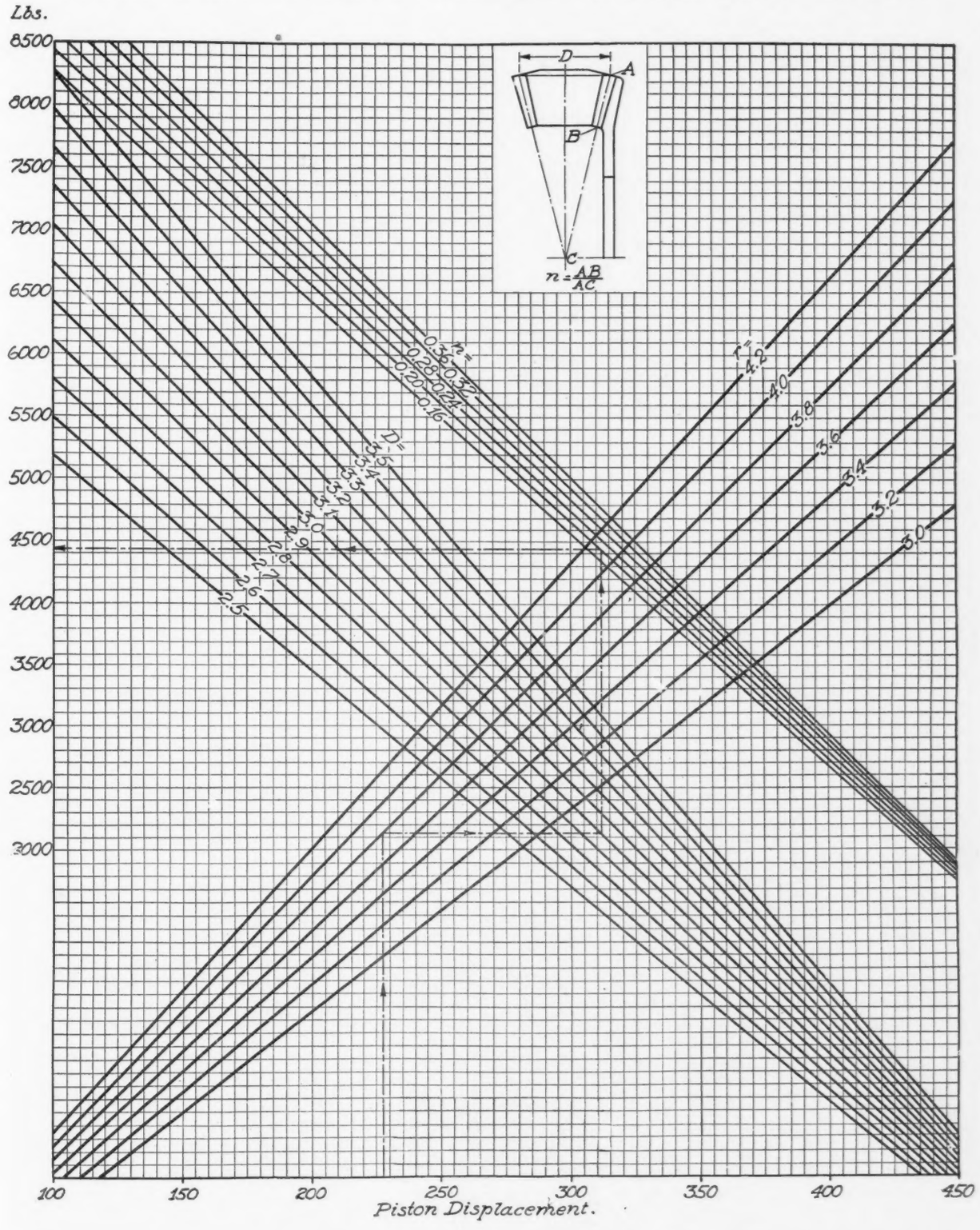
In order to determine the minimum pressure required in valve springs for use in connection with the ordinary mushroom type of cam follower and corresponding cam, locate the maximum engine speed on the bottom scale; proceed upward to the incline representing the center distance D of the base and top circles of the cam; thence horizontally to the incline representing the weight of the valve reciprocating parts, and thence vertically to the scale at the top

Bearing Loads Due to Final Drive Worm Gears



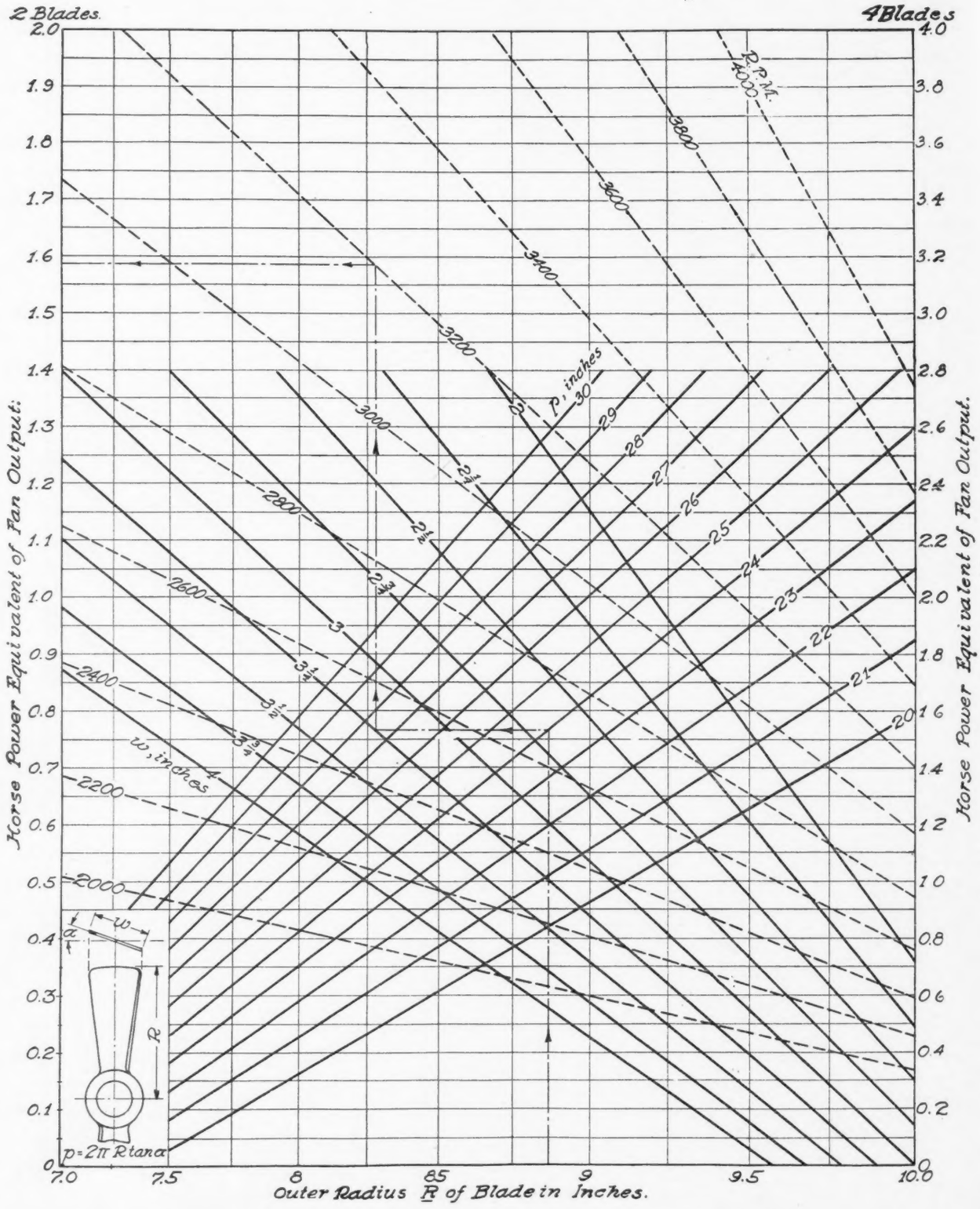
This chart serves to determine the thrust load on the worm wheel and the radial load on the worm bearings. On the bottom scale locate the engine torque; proceed upward to the incline representing the transmission low gear ratio; thence horizontally to the incline representing the pitch diameter of the worm, and thence upward to the scale at the top, where the thrust load on the worm wheel bearings can be read off. From where this latter vertical line intersects with the incline representing the pitch angle, proceed to the scale at the right, where the radial load on the worm bearing may be read off

Tooth Load on Bevel Pinions of Rear Axle Drives



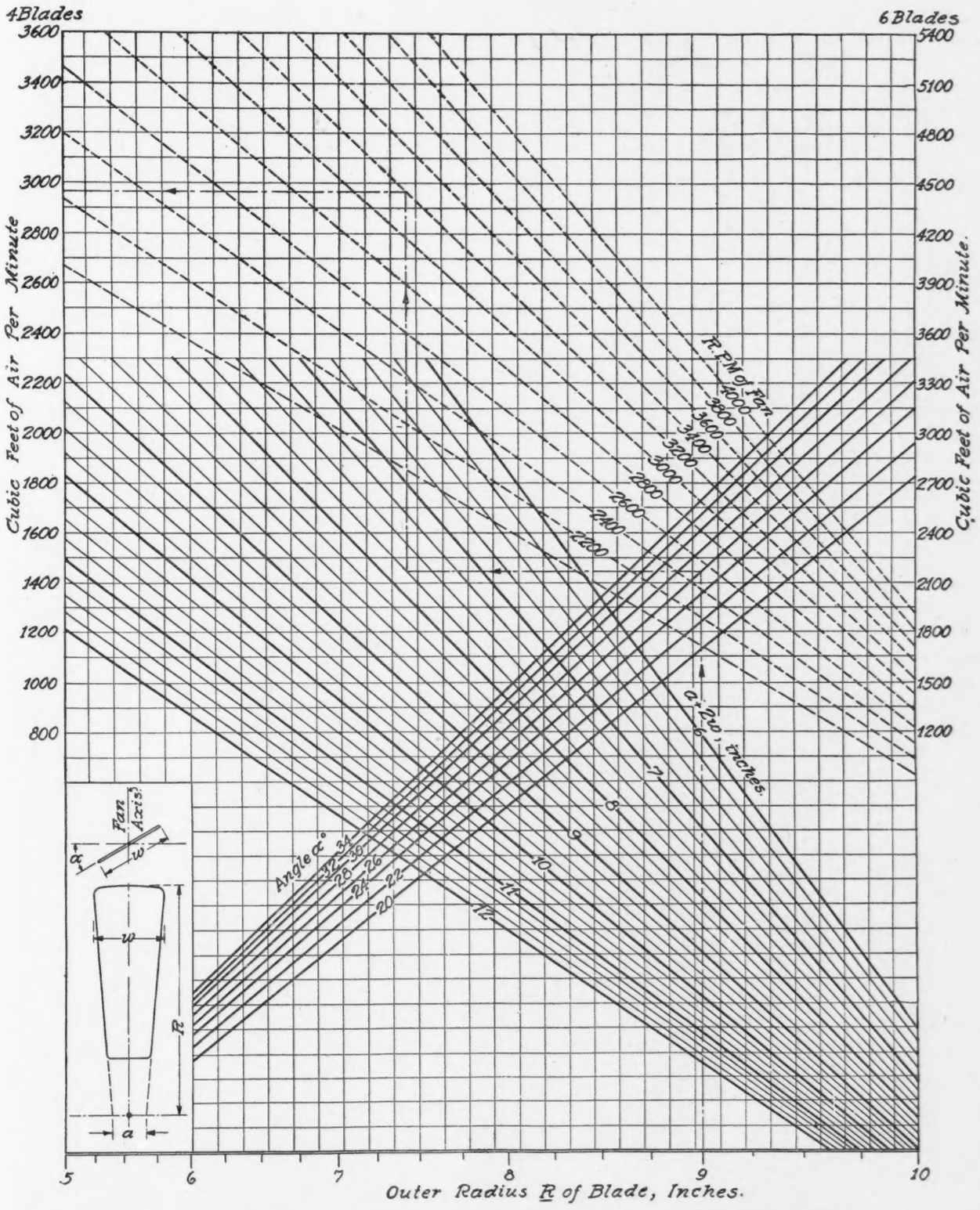
This chart serves to find the tangential force on the rear axle bevel pinion of a car, for full engine power on low gear or reverse, the tangential force being reduced to the mean effective pitch diameter of the pinion. The bottom scale represents the piston displacement of the engine in cubic inches; r is the reduction radio of the low gear or reverse in the transmission; D is the pitch diameter of the pinion and n a ration defined by the sketch.

Horsepower Equivalent of Air Delivery of Helical Fans



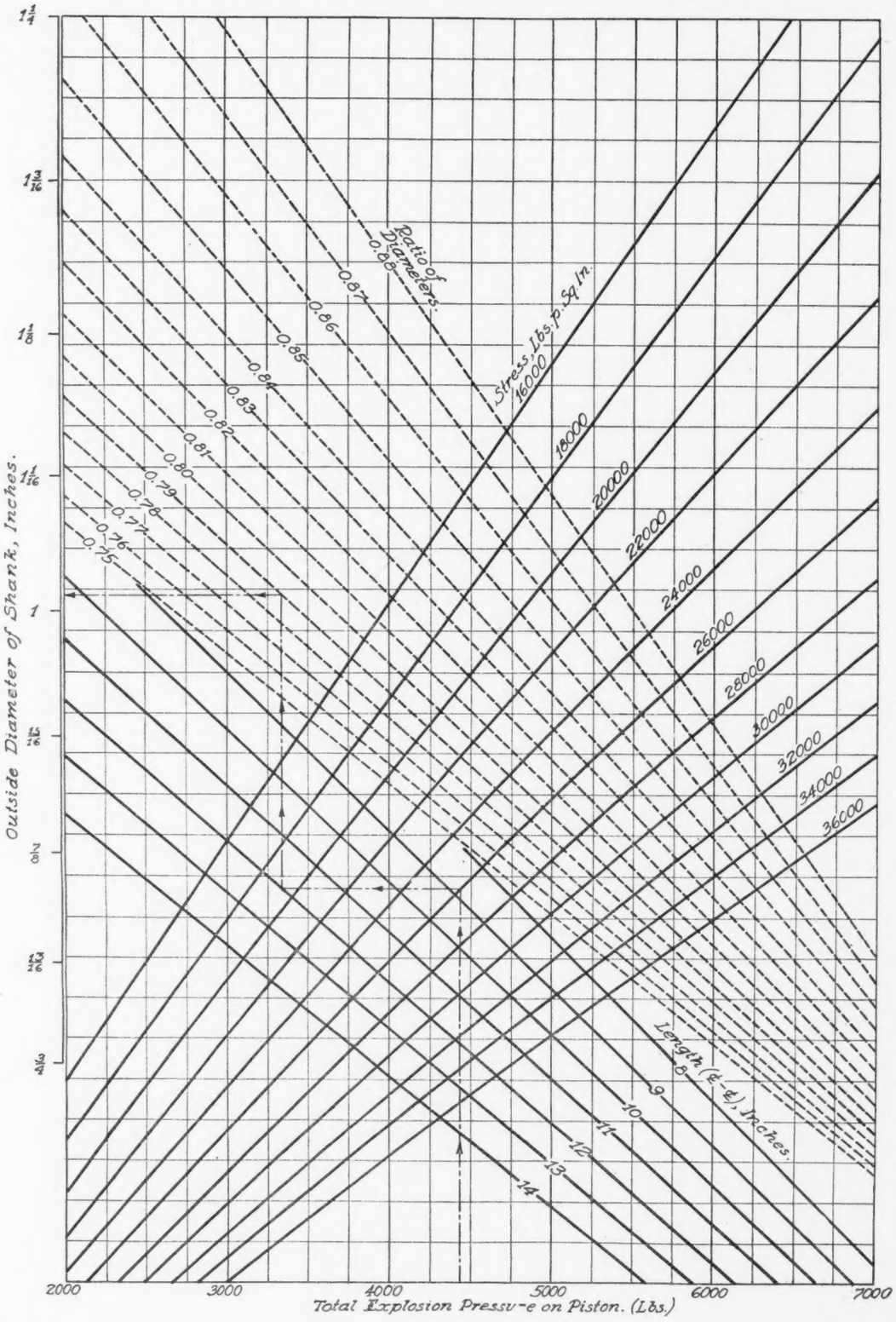
From the above chart the horsepower equivalent of the output of a helical or propeller type fan may be quickly found. The inner radius of the blade has been assumed to be two inches throughout. Any variations in this dimension will introduce only a negligible error

Capacity of Fans With Tapering Plane Blades



This chart shows the theoretical or maximum air delivery of the fans and permits of comparing fans of different number, size and inclination of blade. In order to simplify the chart the inner radius of the blades has been disregarded and a constant allowance of 2½% made for the portions of the blades cut off at the inner end. If the inner radius does not exceed one-third the outer radius the error introduced by the expedient is very slight

Capacity of Tubular Connecting Rods



By means of the above chart the necessary diameter of a tubular connecting rod can be determined. Locate the maximum total explosion pressure on the piston on the bottom scale; proceed upward to the inclined line representing the allowable stress for the material used; thence horizontally to the line representing the center-to-center length of the road; thence vertically upward to the incline representing the ratio of the inside to the outside diameter of the section and thence horizontally to the scale on the left, where the required outside diameter can be read off

Just Among Ourselves

C. C. Hance a Pioneer in Excise Tax Fight

THE final success of the industry in its fight to have the Federal tax on motor vehicles removed is an excellent example of a unified cooperation transcending even the powerful personalities involved in it. Some of those who led the industry's fight most actively in the early days of the discussion watched the battle in its final throes go forward under new leadership, but always there was the sinking of self into the cause. Outstanding among those who pioneered the tax fight for the industry and who later saw their original ideas carried forward to success is C. C. Hanch, formerly chairman of the N.A.C.C. tax committee and now general manager of the National Association of Finance Companies. So important and so far-reaching were Mr. Hanch's basic contributions to the tax fight that we are constrained to add our hearty second to the statement made by George M. Graham in a letter written to Mr. Hanch following the signing of the tax bill by President Coolidge. "Others may think in terms of new leaders," Mr. Graham wrote, "but I cannot but recall that you were the pioneer leader in the fight when the issues were new, when our cause was unpopular and when a great mass of educational work lay ahead. Naturally many have contributed to the effort now successful, but I am going to register my compliments and congratulations to the then chairman of the tax committee, your good self."

* * *

Here's Our Experience —Tell Us Yours

EVERYBODY'S agreed on the necessity for good service. Everybody's talked a lot about it. Every factory has done something; some factories have done a good bit. Our publishing experience indicates, however, that the repetition of specific examples helps materially to impress and keep vivid the existence of any condition or situation. Hence the inauguration of "Service Experiences," the first of which follows. We'll be glad to have contributions.

Service Experiences

No. 1

A blowout. We enter good-looking city garage and ask one of two men seated in office at front, "Someone here can change a tire?" Answer, "Yes, drive 'er right in." We do. Nothing happens. Three men by this time sitting in office. Five minutes pass as we wait toward back of garage. Finally, Swedish mechanic sticks head out from uttermost rear and asks: "Want something?" "Yes, tire changed." He comes over immediately, does quick, efficient job. Tells us pleasantly he hopes we'll get good mileage out of the new tire, and we're off. Three "executives" still polishing seats of chairs in the office and talking to one another. Wish we could get mechanic better job in good shop.

* * *

Big Year for Mergers and Engineering Progress

THE year 1928 is turning out to be significant from an automotive standpoint in several respects. More than any previous year it is being marked as the period in which the trend toward consolidations and mergers really got into its stride and perhaps will turn out to have been the year in which that trend reached its greatest height. We are going to hazard the guess, too, that it will be marked as the year in which the automobile industry broke the bonds of tradition from an engineering standpoint to a greater extent than at any time in five years. That's a bit risky, we realize, as follow-the-leader policies seem to have been growing rather than lessening. The dangers have apparently outweighed the possible advantages of being distinctly different in the minds of a majority of executives. The time seems to have come competitively, however, when those risks must be taken; the industry as a whole, perhaps, and individual manufacturers certainly in some instances may have reached a point where they can no longer afford not to take the chance.

* * *

"Something New" is the Slogan

FROM what we have been able to glean about body and chassis changes under way in the engineering departments of several very important companies, the break seems to have come. Really big companies are going to step out this year, building onto the basis of sound past practice striking innovations in body design and mechanical construction. The day of holding fast to public favor simply by continuing to do well a job already recognized as meritorious seems to be past. A definite, positive reaching out and grasping for something new, something better, something in advance, seems to have become a routine necessity for automotive thinking and automotive merchandising practice. Constant change—real change—seems certain to be a routine rather than an unusual part of the policy of successful automotive concerns from now on. —N.G.S.

Truck Engine Design With Demand

Trend toward six-cylin for heavy-duty vehi of freedom from

By AUSTIN M.
Automotive Consulting

ONLY a short time ago truck design appeared to be almost entirely stabilized. The low-speed engine, great platform heights, large-diameter solid rubber tires and low vehicle speeds were generally accepted, and the only discordant note was the debate regarding the preferable form of final drive. Today, however, the truck must be able to keep up with the generally increased speed of traffic and must possess greater accelerating and decelerating ability, as well as greater sustained speed. Improved roads have benefited the truck as well as the passenger car, although trucks will continue to be used also away from the beaten highway, where adverse conditions must be coped with.

Truck design is now in a state of transition and in the evolution of the new type experience gained with buses will have a marked effect.

Most of the new characteristics of the modern truck are due to changes in engine design. The most marked trend at present is the use of six-cylinder engines, not only on the smaller trucks, to which they were applied first, but also on the larger sizes.

The inherent freedom from vibration of the six is a big factor in high-speed work. Higher crankshaft speeds are possible, and beside the practical elimination of the destructive effects of vibration on chassis and body, the physical and mental relief enjoyed by the driver, is a considerable asset. The lighter flywheel of the six increases the accelerating ability of the truck; the more sustained torque at higher speeds is most important, and the relatively smaller unit combustion chamber volume is an aid in supressing detonation.

Crankshaft Design

In considering the trend in design, a logical starting point is the crankshaft. Carbon steel (0.45 per cent) is the favorite material for this unit, with chrome-nickel steel following. Since the modulus of elasticity is practically the same for all steels, there is little choice from the standpoint of stiffness. The mounting of the shaft is more important from this point of view than material selection. In spite of the excellent wearing qualities of shafts with case-hardened journals, this practice has not grown.

In order to make four-cylinder engines more smooth running, the counterweighted shaft has been introduced. A typical example is shown in Fig. 1, the balance weights being forged integral. Piston and connecting rod are a little more difficult to remove, the piston being allowed to follow the counterweights as the crankshaft is being revolved, but this slight disadvantage is more than compensated for by the smoother running and decreased bearing leads.

The three-bearing crankshaft predominates in four-cylinder engines, while four and seven main bearings are used in the six-cylinder type, the latter number particularly in the latest designs. Crankshaft diameters are increasing and 3-in. main bearings for a 4⅜ by 4¾ in. cylinder is typical of the latest practice. With such massive main journals the crankpin diameter is made from 80 to 85 per cent of the main journal diameter. With the more conservative practice of the earlier designs, the main and connecting rod journal diameters

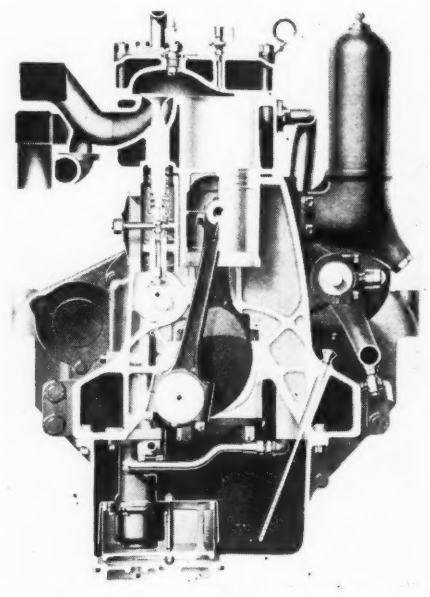


Fig. 1 (at left)—Buda four-cylinder counterweighted crankshaft. Fig. 2 (right)—Waukesha engine with box sections cast in crankcase

Valve spring surge, which has attained considerable prominence in the passenger car field due to high engine speeds, also has bothered truck engineers, owing to the larger number of turns and heavier gage of spring wire required in this service, which results in low critical speeds. If conditions are just right there may be violent periods at as low a speed as 400 r.p.m.

Valve lifters of the mushroom type are being used in increasing number, due to the more rapid opening of the valve, which results in a better valve-opening area diagram. Formerly this type was rather noisy, but this has now been overcome by suitable cam ramp design. This ramp has been incorporated also in the roller-follower type of cam. Mushroom type lifters are usually of case-hardened steel or have the lately introduced chilled-iron face welded to carbon steel stems. Lifter rollers are usually made of .20 per cent carbon steel, case-hardened. Detachable cluster units for the lifters are popular. Camshafts have been increased in diameter for greater rigidity.

The aluminum piston is coming into use in truck work. Its higher heat conductivity tends to suppress detonation and to improve lubrication due to the lower temperature of the skirt portion. Higher combustion temperatures are therefore permissible. The invar-strut construction is most widely used at present. However, weight reduction cannot be carried to the same point as in passenger car engines, as the operating conditions are more severe in truck work and heavier sections must be used in order to effectively carry off the heat. Cast iron will probably remain popular for a long time to come. Foundry practice producing thin, uniform walls and ribbed design have lightened them considerably, and the natural bearing qualities of cast iron, which enables it to stand up under momentary adverse conditions of lubrication, are unequaled in other metals.

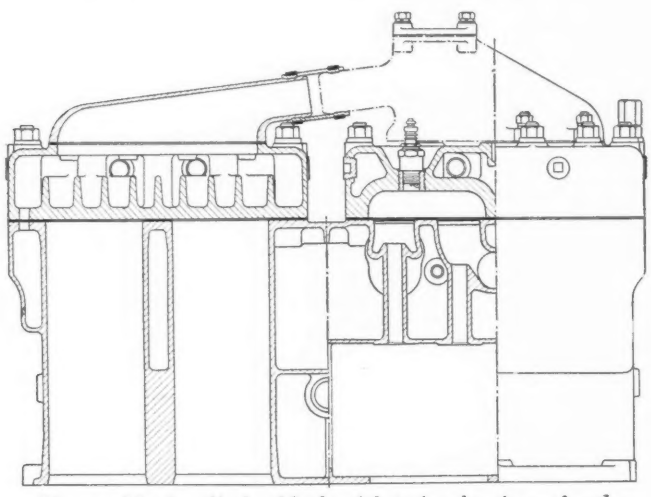
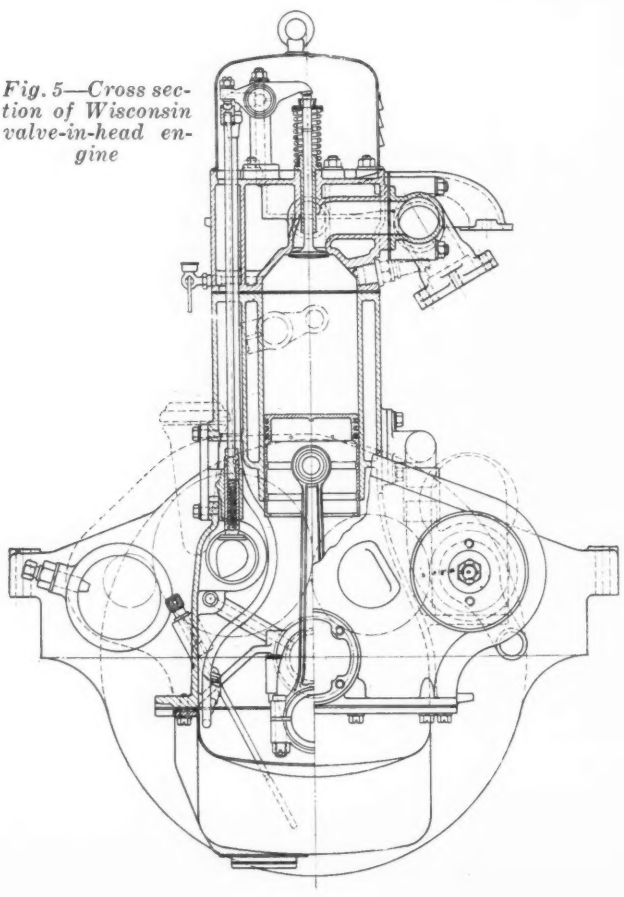


Fig. 4—Mack cylinder block with twin aluminum heads

Fig. 5—Cross section of Wisconsin valve-in-head engine



Three piston rings are usual in engines of less than 4-in. bore, and four in larger cylinders. It is general practice to use one oil regulating ring of some type.

Piston pins are made larger in diameter to cut down the unit pressure, and in some cases are lubricated by direct pressure. The floating pin is gaining popularity, being usually retained in place

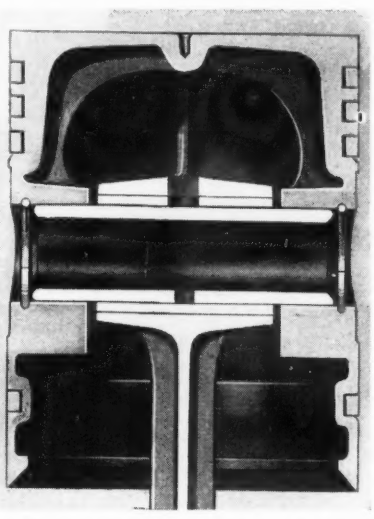


Fig. 7—Buda floating piston pin

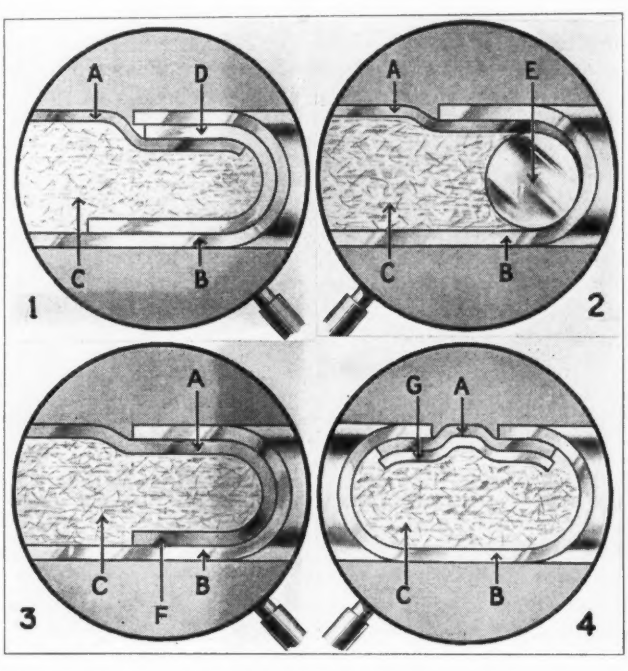


Fig. 6—Victor gasket constructions. 1—Extra layer D of reinforcing metal. 2—Welded copper wire ring E for cylindrical combustion chambers. 3—Double overlap construction. 4—Extra copper insert G to reinforce narrow bridges

Keeping Pace *for* Speed

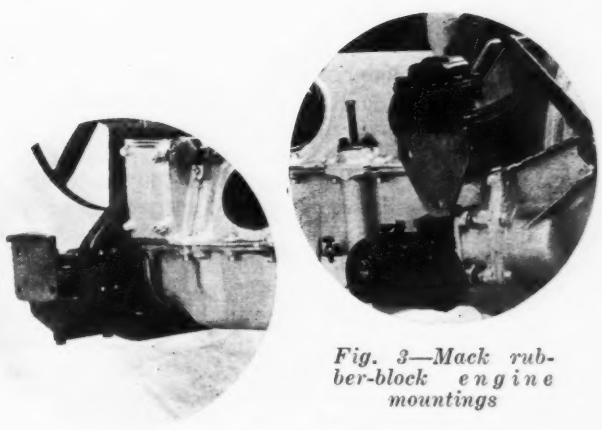


Fig. 3—Mack rubber-block engine mountings

der types even cles because vibration

WOLF
Engineer

are alike. Rigidity in modern shafts is aided by the overlapping of the contours of the crankpin and main journal in the end view, thus giving continuity of some of the metal without overhang. With such rugged construction, vibration dampers are not needed. Ball bearing mounting, while resulting in a more compact engine, has not been applied to any other trucks besides the two models in which these bearings have been incorporated for many years.

Rigidity being so essential, the crankshaft requires adequate support. Crankcases are well ribbed and trussed, the joint between the two sections usually being placed well below the shaft center in order to gain vertical depth. Fig. 2 shows a design with a box-section cast at each side in continuation of the interior trussing, imparting stiffness in both vertical and horizontal planes. Horizontal stiffness is sometimes obtained by the use of a thick, wide flange at the joint. Considering the dynamic loads on the main bearings at high speeds, which are represented by a graph of practically elliptical form, it is obvious that provisions must be made to insure horizontal rigidity of the case.

Crankcases are generally supported at three points. Fortunately, truck makers have not been faced with the troubles that the passenger car manufacturers have gone through as a result of the adoption of balloon tires. The latter are reverting to four-point suspension in an attempt to make the crankcase a backbone for a frail front structure.

Engine Mountings

Resilient engine mountings—now popular in passenger car practice—will no doubt gain in the truck field. Their use somewhat complicates the problem of tying the frame together at the point where the bell housing now acts as a cross member. It is necessary not only to provide sufficient rigidity, but the cross member must not interfere with the removal of the crankcase lower half, the transmission and clutch unit. Resilent rear supports should be close to the center of percussion of the engine. Fig. 3 illustrates a front and a rear mounting, the latter incorporating a substantial frame tie connection.

Cylinder blocks cast separate from the crankcase and those cast integral therewith are about equally divided. There is no question but that the former are preferable from the service point of view, while the latter give greater rigidity. The use of nickel, or nickel and chromium, in the iron has resulted in a more uniform micro-structure and has given greater wear resistance, besides better machinability. A Brinell hardness in excess of 220 is obtainable.

There is a trend toward the use of a two-piece head. Easier handling, assurance of greater uniformity of pressure from the hold-down studs, less over-all expansion and less liability of warpage are some of its advantages over the long, shallow, one-piece casting. Fig. 4 shows such a head construction applied to a four-cylinder job, and is notable because of the use of aluminum.

Combustion Chamber Design

The larger volume of the combustion chambers tends to increase trouble from detonation, and higher engine speeds have necessitated the use of more compact combustion chambers. While Ricardo-type heads are popular, the valve-in-head engine gives a compact combustion chamber, with easy entry and exit for the gases, considering the number of changes in the direction of flow. A typical valve-in-head design is shown in Fig. 5.

The practice of machining combustion chambers is being introduced to insure equality of cylinder content and smoothness of walls. Compression ratios are being stepped up, reaching 4.65 and 5 to 1. Aluminum, with its superior heat conductivity, is being employed to help minimize detonation. Use of this metal for the cylinder head is a distinct aid in the equalization of head temperatures, preventing localized heating in the combustion chamber metal and in that way making higher compression ratios feasible.

Continuous exposure to high pressures and temperatures is the lot of the cylinder head gasket. Development of this unit has kept pace with the increasing demands placed upon it. More thoroughly annealed copper, free from scale and discoloration, special asbestos sheet used in place of the former millboard, and special stamping operations have made this possible. Fig. 6 shows several constructions of reinforced gaskets.

Silicon-chromium steel is almost universally used for exhaust valves, and nickel steel for the inlet valves. The use of exhaust valves slightly smaller in diameter than the inlet valves is fast becoming common practice. Larger fillets are used under the head, for better heat conduction. The salt-cooled valve, borrowed from aviation, has been introduced into bus engines and its performance is being watched by truck engineers. Conventional valve timing runs about as follows:

MODELS	TYPE	INLET Opens Past T. D. C.	INLET Closes Past B. D. C.	EXHAUST Opens Before B. D. C.	EXHAUST Closes Past T. D. C.
	4-cylinder	10	30	40	5
New 4- and	6-cylinder	5	45	45	5

by snap rings, as shown in Fig. 7. Snap rings are more in favor than soft metal end plugs or the use of a piston ring centrally located over the piston bosses. The floating pin must be a snug fit in the piston when cold, otherwise excessive clearance will develop. The tapered wall, heaviest at the center, is used considerably in view of its beam type structure and the resistance of the heavier center portion against distortion from clamping in the rod. As a positive guarantee against distortion the hollow-drilled pin with a solid center portion (Fig. 8) has been introduced.

Connecting Rods

Connecting rods are usually of 0.35-0.40 per cent carbon steel, of I-section, and of a length slightly greater than twice the stroke, to minimize rod angularity. One new engine has a rod length equal to two and a half times the stroke. Chrome-vanadium steel is used to some extent, as is the tubular type rod. In view of the comparatively large big-end diameters, the merging of them into the beam section involves a careful study of proportioning. Fig. 9 shows a modern rod for a floating piston pin (note reinforcing rib at pin boss) which has a poured-in babbitt big-end bearing. The latter practice is making headway, cutting down weight and allowing better heat dissipation from the journal. Replacement of a bearing requires exchanging for a rebabbitted rod. The bronze-back shell with heat radiating flanges, as shown in Fig. 10, is used to some extent. Both constructions take cognizance of the heat generated at the crankpin.

Face widths of front end gears have been increased to give added life. The fluctuating load of an air compressor does not deal lightly with a gear train. Probably a three-cylinder compressor will be developed, which would flatten out the torque peaks of the compressor load.

In the newer designs the fan and water pump are combined, as in passenger car engines. It is essential that the unit be capable of being removed without disturbing the radiator. By coring mating passageways in the block, the unit can be taken out without breaking hose connections, by simply loosening the fan belt and removing a few cap screws. Simplification of the powerplant and clean-cut appearance result from this design. Fig. 11 illustrates such a construction. V-belt drive is increasing and makes for compactness. Thermostatic control of the water circulation has never taken hold as in passenger car work, due to the more continuous operation of the truck. Directing the cooling water from the pump through cored passageways or special distributors directly toward the exhaust valves is a favorite practice. The design of the

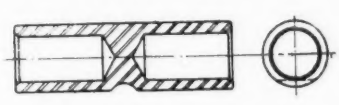


Fig. 8—Lycoming solid-center piston pin

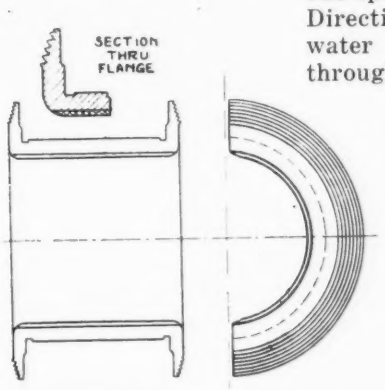


Fig. 10—Federal Mogul radiated type flange bearing

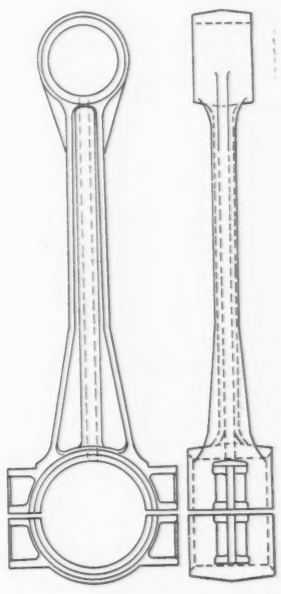
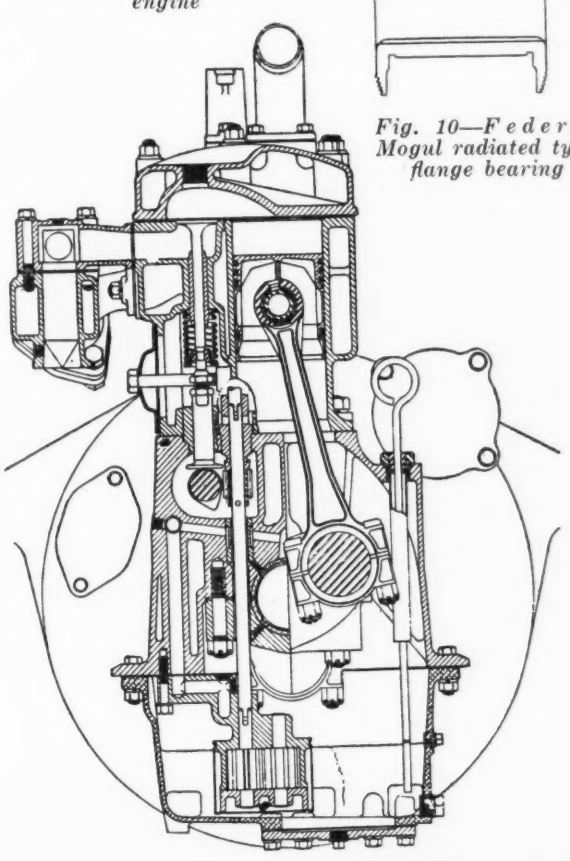


Fig. 9—Buda connecting rod

Fig. 11—Section of Buda engine



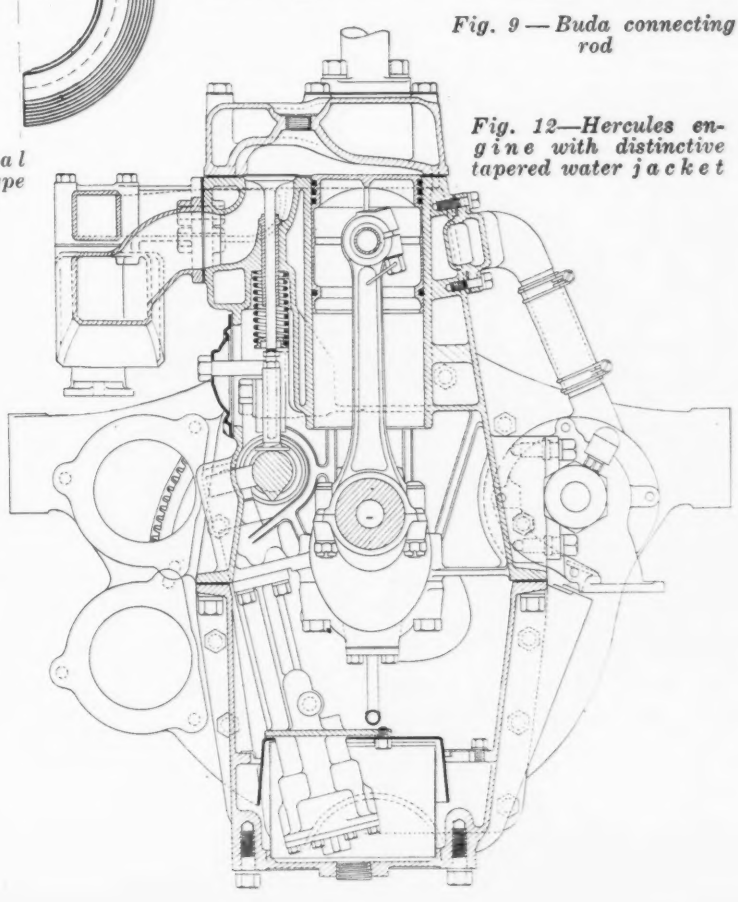


Fig. 12—Hercules engine with distinctive tapered water jacket